ENGINEERING EXPERIMENT STATION

Georgia Institute of Technology

PROJECT INITIATION

Date Dec. 27, 1956

PROJECT TITLE: Special Purpose Marine Power Unit

PROJECT NO: A-313

PROJECT DIRECTOR: W. C. Boteler

SPONSOR: Navy Dept/ BuShips

EFFECTIVE: Dec. 7, 1956 ESTIMATED TO RUN UNTIL: May 31, 1959

TYPE AGREEMENT: Contract NObs 72217

Assigned to Mechanical Sciences Division

Copies To:

Project Director	Purchasing
Director	Engineering Design Services
Associate Director	Technical Information Section
Assistant Director(s)	Photographic Laboratory
Division Chiefs	Shop
Accounting	Security Officer Capt. Williams
General Office Services	Report Section
Rich Electronic Computer Center	

ES FORM 400 (Rev 10–56)

GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station

PROJECT TERMINATION

Date 12-11-67

PROJECT TITLE: Special Purpose Marine Power Unit

PROJECT NO: A-313

PROJECT DIRECTOR: Mr. Lee Knight

SPONSOR: U. S. Depart. of the Navy, BuShips

TERMINATION EFFECTIVE: November 15, 1967

CHARGES SHOULD CLEAR ACCOUNTING BY: 12-30-67

Project ~~XXXXXXX~~ Director has authorized the transfer of contract overruns to Account No. ~~XXXXXXX~~ E-501-002.

Mechanical Sciences

Reports 300.A-313

COPIES TO:

Project Director
Director
Associate Director
Assistant Directors
Division Chief
Branch Head
Accounting
Engineering Design Services

General Office Services
Photographic Laboratory
Purchasing
Shop
Technical Information Section
Security

Form EES 402 (R10-62)

UNCLASSIFIED

UNCLASSIFIED CONFIDENTIAL

A-313

14

GEORGIA INSTITUTE OF TECHNOLOGY

ENGINEERING EXPERIMENT STATION

ATLANTA 13, GEORGIA

31 March 1961

Classification changed to UNCLASSIFIED

Auth: BuShips Ltr 631 G-304 Dated: 29 June 1961

By

Chief, Bureau of Ships
Department of the Navy
Washington 25, D.C.

Attention: Code 631

Subject: Progress Report No. ~~3~~ 4, Contract No. NObs 72217
Phase III, Index No. SF011-02-12, Task 2553

Dear Sir:

This report summarizes the work done during the period from February 21 to March 21.

I. NIMROD I

The test schedule for the Nimrod I was changed to the two weeks beginning on March 20, 1961, due to changes in ship schedules. The reel has been completed and will be available for the sea trials. Due to the short schedule it is not anticipated that the moored mine sweep gear will be towed during these tests. Tentative arrangements have been made to share the U.S.S. ASSURANCE with Project S-101 on a 7 hour per day basis during part of May and June. It is anticipated that a definite schedule will be set after all the interested personnel have been consulted.

Due to the shift of the test starting date from March 27 to March 20, the readout amplifiers have not been checked completely. Final checkout will be made at USNMDL prior to loading the equipment aboard ship.

II. NIMROD II

The transmission has been completed and run in at low speed. The shroud outer skin has been attached to the inner shell and will be filled with polyurethane foam within two weeks. The struts have been attached to the inner shroud surface. The control surfaces have been completed. The shafts and bushing supports are being fabricated

The motor support shell has been fabricated and is being machined. The propulsion system will be assembled when this piece is completed.

UNCLASSIFIED CONFIDENTIAL

UNCLASSIFIED

Direct current motor type actuators will be used on the first prototype due to the availability of suitable actuators. The control system dynamics are being analyzed to determine the feasibility of using an on-off-trail type of actuation on subsequent models. This type of system permits the use of inexpensive hydraulic solenoid valves and actuators.

The power supply for operation of the control system components and the tracking beeper will be provided by rectifying and regulating the variable frequency 400 cycle propulsion motor supply. This arrangement will permit up to 8 wires for vehicle control.

The first water tests are scheduled tentatively for the last week of April at the Lake Arabia facility near Atlanta. The small size of the lake will permit only hovering type operation. Stability during hovering is expected to be the most difficult phase of the test program. Therefore, these tests will be run before sea tests on a moving boat are scheduled.

Design work for the cable reel drive and the vehicle dolly is proceeding and construction of these items will begin shortly.

The control system studies are continuing. Roll and pitch stabilization will be provided by a D.C. powered vertical gyro. The Nimrod I bottom follower circuit card will provide the altitude control.

Respectfully submitted:

Winston C. Boteler
Project Director

Approved:

T.W. Jackson
Chief, Mechanical Sciences Division

V

A-313

GEORGIA INSTITUTE OF TECHNOLOGY

ENGINEERING EXPERIMENT STATION

ATLANTA 13, GEORGIA

October 27, 1961

Chief, Bureau of Ships
Department of the Navy
Washington 25, D.C.

Attention: Code 631

Subject: Letter Progress Report No. 11, Contract No. NObs 72217, Phase III, Index No. SF011-02-12, Task 2553

Dear Sir:

This report summarizes the work done during the period from September 21 to October 21, 1961.

A tentative test schedule for the Diana vehicle has been set up at USNMDL for the weeks of November 13 and 20, 1961. It is probable that a YSD type ship will be used. It is anticipated that these preliminary developmental tests will provide all the necessary data concerning the vehicle dynamics.

The cable reel drive has been completed and is being tested to maximum loads. The reel drive uses a small rubber covered pinch roll assembly, rather than a set of friction rolls.

All fabrication work on the Diana vehicle has been completed. The system will be operated with the vehicle in the test tank during the remainder of the month and the first week in November. The final trim and ballast adjustments will be made at USNMDL. The vehicle will be tested first without any additional equipment ahead of the vehicle control and motor section. Later tests will include various forward sections.

An analysis of the control cable is continuing and should be completed around November 1. Stress-strain curves of the Dacron strain members are being made. When these data are available, the complete analysis will be forwarded by letter to Code 631.

Respectfully submitted:

Approved:

Winston C. Boteler
Project Director

Thomas W. Jackson
Chief, Mechanical Sciences Division

QUARTERLY PROGRESS REPORT
NO. 20

PROJECT A-313-001

WINSTON C. BOTELER

Contract No. N600-59880

December 29, 1963 to March 29, 1964

Prepared for
U.S. Navy Mine Defense Laboratory
Panama City, Florida

1964

Engineering Experiment Station
GEORGIA INSTITUTE OF TECHNOLOGY
Atlanta, Georgia

GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station
Atlanta, Georgia

QUARTERLY REPORT NO. 20

PROJECT A-313-001

By

WINSTON C. BOTELER

CONTRACT NO. N600-59880

DECEMBER 29, 1963 TO MARCH 29, 1964

Prepared for
U. S. NAVY MINE DEFENSE LABORATORY
PANAMA CITY, FLORIDA

I. SUMMARY

The following report concerns the design, fabrication, and testing of a remotely controlled underwater vehicle (Diana).

II. EXPERIMENTAL

A. Phase IV vehicles

All design work has been completed on the Nos. 4 and 5 Diana vehicles. Drive power will be supplied by two 6 pole A.C. induction motors mounted horizontally opposed on the shroud exterior. The transmission consists of two separate units. The first stage reduction, which is attached to the motor, consists of a single 2.76:1 helical gear set. A quill shaft connects the first stage output with a 4.88:1 spiral bevel gear set which drives the propellers. The maximum propeller speed will be 570 rpm.

The vehicle design has been changed to permit bolting up the shroud, struts, and center body sections. This will facilitate maintenance and repair. Attachment points have been provided on the front and rear center body sections for attaching the instrument and actuator control units.

Wiring will be carried around the shroud in a one inch square channel in the interior shroud skin. This will permit easy access to all connections for repair or replacement.

III. PROGRAM FOR THE NEXT REPORTING PERIOD

It is anticipated that the vehicles will be completed during the next reporting period.

Respectfully submitted,

Winston C. Boteler
Project Director

QUARTERLY PROGRESS REPORTS
NOS. 21 AND 22

PROJECT A-313-001

LEE H. KNIGHT

Contract No. N600-59880

March 29, 1964 to September 29, 1964

Prepared for
U. S. Navy Mine Defense Laboratory
Panama City, Florida

1964

Engineering Experiment Station
GEORGIA INSTITUTE OF TECHNOLOGY
Atlanta, Georgia

GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station
Atlanta, Georgia

QUARTERLY REPORT NO. 21

PROJECT A-313-001

By

LEE H. KNIGHT

CONTRACT NO. N600-59880

MARCH 29, 1964 TO JUNE 29, 1964

Prepared for
U. S. NAVY MINE DEFENSE LABORATORY
PANAMA CITY, FLORIDA

I. SUMMARY

The following report concerns the design and fabrication of a remotely controlled underwater vehicle (Diana).

II. EXPERIMENTAL

A. Phase IV vehicles

Final design and detail shop drawings have been completed on the Nos. 4, 5, and 6 Diana vehicles. All materials and castings for the vehicles have been received and checked prior to beginning machine shop work.

Because of the extremely small rotor-stator air gap required for operation of the electric drive motors, it has become necessary to request the vendor (Task Motor Corp., Aneheim, California) to manufacture and assemble the motors as finished units, thus obviating the necessity for time consuming and expensive close tolerance machine work at Georgia Tech. Accordingly, the delivery data for the first two motor assemblies has been moved up to 27 July 1964.

B. Cable handling equipment

Preliminary design work on the cable handling equipment has been initiated.

III. PROGRAM FOR THE NEXT REPORTING PERIOD

It is anticipated that Diana vehicle No. 4 will be completed and delivered to the U. S. Navy Mine Defense Laboratory during the next reporting period.

Respectfully submitted,

Lee H. Knight
Project Director

GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station
Atlanta, Georgia

QUARTERLY REPORT NO. 22

PROJECT A-313-001

By

LEE H. KNIGHT

CONTRACT NO. N600-50880

JUNE 29, 1964 TO SEPTEMBER 29, 1964

Prepared for
U. S. NAVY MINE DEFENSE LABORATORY
PANAMA CITY, FLORIDA

I. SUMMARY

The following report concerns the design and fabrication of a remotely controlled underwater vehicle (Diana).

II. EXPERIMENTAL

A. Phase IV vehicles

Diana vehicle No. 4 propulsion unit was completed and delivered to the U. S. Navy Mine Defense Laboratory on 28 September 1964, together with two Diana vehicle cables.

Fabrication of Diana vehicle No. 5 is now considered to be 90 per cent complete. Diana vehicle No. 6 is approximately 25 per cent complete and some spare parts have been fabricated.

B. Cable handling equipment

Design work has continued on the cable handling equipment. The unit will consist of two drums each capable of storing 1200 feet of Diana vehicle cable. The two drums will be serviced by a single boom which can be easily moved from one drum center to the other. Each drum will be equipped with power and instrument slip rings and a hydraulically actuated braking system. Clutching of the drums into the drive system will be performed manually. Drive power will be furnished by a 10 horsepower, silicon rectifier controlled motor-reducer unit which allows speed adjustments from 0 to 10 ft/sec cable speed. Except for clutching, the unit will be remotely operated as a safety measure.

It is estimated that the engineering design work on the cable handling system is now 80 per cent complete.

III. PROGRAM FOR THE NEXT REPORTING PERIOD

It is anticipated that Diana vehicle No. 5 will be completed and delivered to the U. S. Navy Mine Defense Laboratory during the next reporting period.

Respectfully submitted,

Lee H. Knight
Project Director

QUARTERLY PROGRESS REPORTS
NOS. 23, 24 and 25

PROJECT A-313-001

LEE H. KNIGHT

Contract No. N600-59880

29 September 1964 to 4 June 1965

Prepared for
U. S. Navy Mine Defense Laboratory
Panama City, Florida

1965

Engineering Experiment Station
GEORGIA INSTITUTE OF TECHNOLOGY
Atlanta, Georgia

GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station
Atlanta, Georgia

QUARTERLY REPORT NO. 23

PROJECT A-313-001

By

LEE H. KNIGHT

CONTRACT NO. N600-59880

SEPTEMBER 29, 1964 - December 29, 1964

Prepared for
U. S. NAVY MINE DEFENSE LABORATORY
PANAMA CITY, FLORIDA

I. SUMMARY

The following report concerns the design and fabrication of a remotely controlled underwater vehicle (Diana).

II. EXPERIMENTAL

A. Phase IV vehicles

Diana vehicle No. 5 propulsion unit was completed and delivered to the U.S. Navy Mine Defense Laboratory in November 1964. Two additional vehicle buoyant cables, together with 1200 feet of non-buoyant shipboard cable were also delivered during this period.

Fabrication of Diana vehicle propulsion unit No. 6 is continuing.

B. Cable handling equipment

Design of the double reel cable handling equipment has been completed and materials for construction have been placed on order.

III. PROGRAM FOR THE NEXT REPORTING PERIOD

It is anticipated that Diana vehicle propulsion unit No. 6 will be completed and delivered during the next reporting period.

Respectfully submitted.

Lee H. Knight
Project Director

GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station
Atlanta, Georgia

QUARTERLY REPORT NO. 24

PROJECT A-313-001

By

LEE H. KNIGHT

CONTRACT NO. N600-59880

DECEMBER 29, 1964 TO MARCH 29, 1965

Prepared for
U. S. NAVY MINE DEFENSE LABORATORY
PANAMA CITY, FLORIDA

I. SUMMARY

The following report concerns the design and fabrication of a remotely controlled underwater vehicle (Diana).

II. EXPERIMENTAL

A. Phase IV vehicles

Fabrication of Diana vehicle propulsion unit No. 6 was completed during this period; however, delivery was withheld pending the outcome of static and dynamic tests of Diana vehicle No. 4, which were commenced in March 1965.

B. Cable handling equipment

Fabrication of the double drum cable handling equipment is now in process. It is estimated that the unit is now 60 per cent completed.

III. PROGRAM FOR THE NEXT REPORTING PERIOD

Testing of the Diana vehicle No. 4 will continue during this period. It is also anticipated that the cable handling equipment will be completed and delivered during the next reporting period.

Respectfully submitted,

Lee H. Knight
Project Director

GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station
Atlanta, Georgia

QUARTERLY REPORT NO. 25

PROJECT A-313-001

By

LEE H. KNIGHT

CONTRACT NO. N600-59880

MARCH 29, 1965 TO JUNE 29, 1965

Prepared for
U. S. NAVY MINE DEFENSE LABORATORY
PANAMA CITY, FLORIDA

I. SUMMARY

The following report concerns the design, fabrication and test of a remotely controlled underwater vehicle (Diana).

II. EXPERIMENTAL

A. Phase IV vehicles

Static and dynamic tests conducted with the Diana vehicle disclosed two major areas of difficulty.

1. The motors over-heated to the point of rotor seizure at relatively low power levels. This problem was referred to the motor manufacturer (Task Corp.). It was found that the rotor-stator air gap was insufficient to compensate for rotor expansion. This deficiency was corrected by the Task Corporation; however, the motors have not been tested subsequent to the modification.
2. The strength of the propeller blades was found to be inadequate for the increased thrust of the Mark IV (two motor) vehicle design. The blades failed at approximately 75 per cent of maximum propeller RPM. Since the blade load varies approximately as the square of the RPM, the blades must be at least 60 per cent stronger to prevent failure. In order to obtain the necessary increased strength of the blades, the thickness will be increased by 50 per cent at the 30 per cent radius point (the approximate root section) This increased thickness will taper linearly to 0 per cent increase at the blade tip. The thickness increase will be accomplished in such a manner that the position of the section mean line relative to the chord line will not be changed, thus preserving the design lift coefficients. Such

a section thickness increase will increase the blade strength at the point of maximum stress (50 per cent radius) by a factor of 84 per cent.

B. Cable handling equipment

The cable handling equipment was delivered to the U. S. Mine Defense Laboratory at Panama City, Florida, during the month of June 1965.

III. PROGRAM FOR THE NEXT REPORTING PERIOD

It is expected that the design for the propeller blade modification will be completed during this period. Dynomometer tests of the modified motors will be accomplished at the U. S. Navy Mine Defense Laboratory and further consideration of the off design condition of the Mark IV vehicle will be made.

Respectfully submitted,

Lee H. Knight
Project Director

QUARTERLY PROGRESS REPORT NO. 28

PROJECT A-313-001

LEE H. KNIGHT

Contract No. N600-59880

29 December 1965 to 29 March 1966

Prepared for
U. S. Navy Mine Defense Laboratory
Panama City, Florida

1966

Engineering Experiment Station
GEORGIA INSTITUTE OF TECHNOLOGY
Atlanta, Georgia

GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station
Atlanta, Georgia

QUARTERLY PROGRESS REPORT NO. 28

PROJECT A-313-001

By

LEE H. KNIGHT

CONTRACT NO. N600-59880

29 DECEMBER 1965 TO 29 MARCH 1966

Prepared for
U. S. NAVY MINE DEFENSE LABORATORY
PANAMA CITY, FLORIDA

I. SUMMARY

The following report concerns the testing of a remotely controlled underwater vehicle (Diana) and the design of cable handling equipment for this vehicle.

II. EXPERIMENTAL

A. Phase IV vehicle

Two redesigned motors have been received from the Task Corporation and have been dynamometer tested at the Navy Mine Defense Laboratory, Panama City, Florida. The dynamometer tests indicate that the power output and cooling charactistics of the motors are satisfactory. These motors, together with redesigned motor fairings have been installed on the No. 3 Mark IV Diana vehicle which is now undergoing dynamic tests at the Navy Mine Defense Laboratory.

Some problems have been encountered with excessive roll torque since the transmissions presently in use are not of the torque splitting type. It is anticipated that these problems can be solved by slight deviations from design pitch angle of the front and rear propeller blades. Tests to determine these blade angle changes are presently being conducted.

Modification and back-fitting of the vehicle transmissions has now been completed, and the final transmission, together with spare parts, will be delivered to the Navy Mine Defense Laboratory during the week of April 18, 1966.

B. Cable handling equipment

Final design for the cable handling drum has now been completed and is now being reviewed by personnel of the Navy Mine Defense Laboratory. Work is presently underway on the design of the reel base and the hydraulic drive system with particular emphasis on the design of a minimum size, adequately cooled fluid reservoir.

III. PLANS FOR THE NEXT REPORTING PERIOD

Tests with the full powered Diana vehicle will be continued during the next reporting period. The Task Corporation has been requested to furnish an accelerated schedule for shipment of the remaining four motors in order to allow an uninterrupted test schedule.

Fabrication of the cable handling equipment will also be carried on during this period.

Respectfully submitted,

Lee H. Knight
Project Director

QUARTERLY PROGRESS REPORT No. 29

PROJECT A-313-001

LEE H. KNIGHT

Contract N600-59880

29 March 1966 to 29 June 1966

Prepared for
U. S. Navy Defense Laboratory
Panama City, Florida

1966

Engineering Experiment Station
GEORGIA INSTITUTE OF TECHNOLOGY
Atlanta, Georgia

GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station
Atlanta, Georgia

QUARTERLY PROGRESS REPORT NO. 29

PROJECT A-113-001

By

LEE H. KNIGHT

CONTRACT NO. N600-59880

29 MARCH 1966 TO 29 JUNE 1966

Prepared for
U. S. NAVY MINE DEFENSE LABORATORY
PANAMA CITY, FLORIDA

I. SUMMARY

The following report concerns component redesign for a remotely controlled underwater vehicle (Diana) and the design and fabrication of cable handling equipment for this vehicle.

II. EXPERIMENTAL

A. Phase IV Vehicle

Testing of the Mark IV Diana vehicle for optimum blade settings has been completed. New Propeller hubs are now being fabricated which incorporate 12 and 10 (front propellar and rear propeller respectively) equally spaced blades which are fixed at the proper blade pitch angle.

The final modified transmission, together with spare parts, was delivered to the U. S. Navy Mine Defense Laboratory during this period.

B. Cable Handling Equipment

The design of the cable handling equipment has now been completed and approved by personnel of USNMDL. Fabrication of the system is now underway.

III. PLANS FOR THE NEXT REPORTING PERIOD

Fabrication of the cable handling equipment will be continued during the next reporting period. It is anticipated that the unit will be completed on or about 30 September 1966.

Respectfully submitted,

Lee H. Knight
Project Director

QUARTERLY PROGRESS REPORT NO. 30

PROJECT A-313-001

LEE H. KNIGHT

Contract No. N600-59880

29 June 1966 to 29 September 1966

Prepared for
U. S. Navy Mine Defense Laboratory
Panama City, Florida

1966

Engineering Experiment Station
GEORGIA INSTITUTE OF TECHNOLOGY
Atlanta, Georgia

GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station
Atlanta, Georgia

QUARTERLY PROGRESS REPORT NO. 30

PROJECT A-313-001

By

LEE H. KNIGHT

CONTRACT NO. N600-59880

29 JUNE 1966 TO 29 SEPTEMBER 1966

Prepared for
U. S. NAVY MINE DEFENSE LABORATORY
PANAMA CITY, FLORIDA

I. SUMMARY

The following report concerns the fabrication of cable handling equipment for a remotely controlled underwater vehicle (Diana).

II. CABLE HANDLING EQUIPMENT

Fabrication of the cable handling equipment has now been completed and preliminary testing accomplished. The unit was delivered to NAVMINDEFLAB on 6 September 1966. Final equipment testing will be conducted under operating conditions during the next reporting period.

III. PLANS FOR THE NEXT REPORTING PERIOD

The cable handling equipment will be final tested during this period by personnel of NAVMINDEFLAB. Three (3) new cables were delivered by Brand-Rex on 10 September 1966.

An interim technical report covering the design of the cable handling equipment will also be submitted during the next reporting period.

Respectfully submitted,

Lee H. Knight
Project Director

QUARTERLY PROGRESS REPORT NO. 31

PROJECT A-313-001

LEE H. KNIGHT

Contract No. N600-59880

29 September 1966 to 29 December 1966

Prepared for
U. S. Navy Mine Defense Laboratory
Panama City, Florida

1967

School of Electrical Engineering
GEORGIA INSTITUTE OF TECHNOLOGY
Atlanta, Georgia

GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station
Atlanta, Georgia

QUARTERLY PROGRESS REPORT NO. 31

PROJECT A-313-001

By

LEE H. KNIGHT

CONTRACT NO. N600-59880

20 SEPTEMBER 1966 TO 29 DECEMBER 1966

Prepared for
U. S. NAVY MINE DEFENSE LABORATORY
PANAMA CITY, FLORIDA

I. SUMMARY

The following report concerns a remotely controlled underwater vehicle (Diana) and the cable handling for this vehicle.

II. VEHICLE

Considerable experimentation and testing have been conducted during this period in the search for a closed cell, foam material suitable for construction of the motor fairings of the vehicle. Unfortunately, no material has been found which will retain its waterproof integrity at the maximum operating depths of the vehicle. However, a polyurothane foam has been found which, when manufactured at a density of approximately 12 pounds per cubic foot, is structurally strong enough to withstand the pressures at operating depths. It is believed that waterproof integrity of this material can be maintained by means of the watertight neophrene covering. Further testing in this area is now being conducted.

III. CABLE HANDLING EQUIPMENT

Tests of the cable handling equipment under vehicle operating conditions have indicated that the stall torque of the gear type hydraulic motor presently in use is insufficient for recovery operation. It is believed that a higher torque capacity piston type motor can be secured which will overcome this difficulty. The technical report on the cable handling equipment was submitted during this period.

IV. PLANS FOR THE NEXT REPORTING PERIOD

It is anticipated that more fairings will be constructed and tested during this period. A new hydraulic motor for the cable handling equipment will also be secured and installed.

Respectfully submitted,

Lee H. Knight
Project Director

QUARTERLY PROGRESS REPORT NO. 32

PROJECT A-313-001

LEE H. KNIGHT

Contract No. N600-59880

29 December 1966 to 29 March 1967

Prepared for
U. S. Navy Mine Defense Laboratory
Panama City, Florida

1967

School of Electrical Engineering
GEORGIA INSTITUTE OF TECHNOLOGY
Atlanta, Georgia

GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station
Atlanta, Georgia

QUARTERLY PROGRESS REPORT NO. 32

PROJECT A-313-001

By

LEE H. KNIGHT

CONTRACT NO. N600-59880

29 DECEMBER 1966 TO 29 MARCH 1967

Prepared for
U. S. NAVY MINE DEFENSE LABORATORY
PANAMA CITY, FLORIDA

I. SUMMARY

The following report concerns the fabrication of motor fairings and buoyancy members for a remotely controlled underwater vehicle (Diana).

II. FAIRINGS AND BUOYANCY MEMBERS

The new motor fairings and buoyancy members were constructed of poured in place polyurethane foam of approximately 12 pounds per cubic foot density. The foam is unicellular; however, at pressures above 50 psi, the cells break down so that the material saturates with water. Therefore neoprene coverings were placed over the foam to maintain watertight integrity. The fairings are similar to the original fairings except that the width was increased by two inches for ease of assembly to the vehicle and to account for the higher density of the material. Three sets of fairings were shipped to USNMDL during this report period and a new hydraulic motor for the cable reel was installed.

IV. PLANS FOR THE NEXT REPORTING PERIOD

Work will proceed on the project final report during the next reporting period.

Respectfully submitted,

Lee H. Knight
Project Director

NOTICE

This document is not to be used by anyone, prior to 12-15 1969 without permission of the Research Sponsor and the Experiment Station Security Office.

TECHNICAL REPORT NO. 2

PROJECT NO. A-313-001

CABLE HANDLING EQUIPMENT FOR MARK IV DIANA VEHICLE

By: Lee H. Knight, Jr.

Contract N600-59880
Prepared for
U. S. Navy Mine Defense Laboratory
Panama City, Florida

1966

26 October 1966

Engineering Experiment Station
GEORGIA INSTITUTE OF TECHNOLOGY
Atlanta, Georgia

GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station
Atlanta, Georgia 30332

TECHNICAL REPORT NO. 2

By

LEE H. KNIGHT

CONTRACT NO. N600-59880

26 OCTOBER 1966

Prepared for
U. S. NAVY MINE DEFENSE LABORATORY
Panama City, Florida

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

I. SUMMARY

This report concerns the design and fabrication of a cable storage and handling system for the Mark IV Diana vehicle. The unit consists of a 20 horse-power (input power), 1500 psi, hydraulic system which drives a cable reel capable of storing 1400 feet of Diana cable and includes instrument and power slip rings.

The unit is capable of recovery speeds up to 10 feet per second at a cable tension of 100 pounds and will recover at slower speeds with cable tension up to 500 pounds. Because of space limitations, a small, 5 gallon hydraulic reservoir was used which results in insufficient heat transfer area for cooling. To alleviate the heating problem, a separate cooling system consisting of a modified automobile radiator and a motor driven blower was installed. Two temperature warning means are also included.

A fail-safe braking system capable of holding torques up to 6000 foot-pounds at the reel was built into the unit. The brake operates hydraulically such that when pressure is not present at the reel drive motor the brake automatically locks.

Control valves and pressure take-off points were furnished at the control panel for two remotely located hydraulic winch motors. An additional cable drum complete with slip rings and bearings was also furnished.

II. INTRODUCTION

The continued shipboard use of the Mark IV Diana vehicle has pointed out the necessity for obtaining a relatively lightweight compact means of rapid launch and recovery of the vehicle under a variety of conditions, and for the storage of the vehicle cable when not in use. Further, because cable difficulties occur quite frequently, a means of rapid cable replacement is also necessary.

In order to meet the above requirements, the following equipment is necessary.

1. A powered boom for lowering the vehicle from the deck to the water on launch and lifting the vehicle on recovery.
2. A powered cable storage reel capable of releasing cable to the vehicle on launch and taking up cable on recovery.
3. A storage reel for a spare cable so designed that cable changes require a minimum of time and can be accomplished at sea.

Experience with equipment previously constructed by Georgia Tech has shown that the incorporation of the above listed capabilities into a single unit results in an unsatisfactory system from both size and weight considerations. For this reason it was decided to separate the lifting and lowering boom from the reel unit and to provide a spare cable drum complete with cable and accessories which is readily interchangeable with the drum in the unit. This spare drum will be stored in whatever space is available until needed. Because the boom will be tied to the superstructure of the ship, it was decided that personnel of the NAVMINDEFLAB would design and build this component while Georgia Tech constructed the cable handling equipment to include a means of powering the necessary boom winches.

Again from previous experience, it has been found that electric drive systems are unsatisfactory for low speed, high torque recovery operation. Since this type of operation is frequently encountered, it was decided that the system should be powered hydraulically in order to take advantage of the static and low speed torque capabilities inherent in hydraulic motors.

The following sections describe the design and fabrication of the cable handling equipment for the Mark IV Diana vehicle.

III. EQUIPMENT REQUIREMENTS

The specifications established for the cable handling equipment are as set forth below.

1. Hydraulically operated unit capable of recovery speeds of 10 feet per second with 100 pounds vehicle drag and 1 foot per second with 500 pounds vehicle drag.
2. System to consist of a single reel base with an additional reel furnished. Reels must be easily and rapidly interchangeable and each must be capable of storing 1400 feet of Mark IV Diana cable.
3. Each reel to have a minimum cable bend diameter of 40 inches and to be equipped with 3 power slip rings capable of handling 40 amps at 2000 volts. Each reel must also be equipped with a minimum of 37 instrument slip rings. Slip rings must be enclosed in a waterproof housing.
4. Hydraulic system must be equipped with a cooling system capable of removing a minimum of 50% of the total electrical power input at a temperature not to exceed 200°F.
5. Temperature warning devices must be provided to indicate approach to and exceeding of maximum operating temperature of 240°F.
6. A fail-safe braking system must be provided for the reel, capable of holding at a cable tension of 3000 pounds. Braking system must be operable in the event of loss of all power.
7. Controls and quick-disconnect take-off points must be provided for two remotely located hydraulic motors.

8. Construction materials must be non-magnetic insofar as possible with standard equipment.

9. Entire unit to be as small and lightweight as possible commensurate with other requirements.

IV. DESIGN

A. Structure

1. Cable Storage Drum

Two cable storage drums were fabricated, each a complete unit containing slip rings, bearings and bearing housings, and 1400 feet of cable. Each drum was constructed in such a manner that replacement of one drum with the other is a relatively simple procedure.

Since the maximum width of the assembled unit was dependent upon the storage drum width, the drum was designed first. In order to store 1400 feet of 1-1/2 inch diameter cable with a minimum bend diameter of 3-1/3 feet and a maximum outside diameter of 5 feet, the drum width was calculated as follows.

a. Number of cable layers

$$N = \frac{R-r}{d} = \frac{30-20}{1.5}$$

$$N = 6.67 \text{ or } 6 \text{ layers}$$

where R = maximum radius of stored cable

r = minimum radius of stored cable

d = diameter of cable

Thus the length of cable for 6 layers and a single turn is

$$L_6 = \pi \left[(D + d) + (D + 3d) + (D + 5d) + (D + 7d) + (D + 9d) + (D + 11d) \right]$$

$$L_6 = 78.5 \text{ feet}$$

where D = minimum cable bend diameter

b. Minimum number of turns of cable for storage of 1400 feet

$$N_T = \frac{1400}{78.5} = 17.8 \text{ or } 18 \text{ turns}$$

c. Minimum width of drum between flanges

$$W_M = N_T(d) = 18 \times 1.5 = 27 \text{ inches}$$

Considering the possibility that the cable will not always be properly placed on the drum, an allowance of 5 inches was made, making the drum width between flanges 32 inches.

The storage drum structurally consists of a hollow stainless steel through shaft 5 inches in outside diameter with a 3-1/2 inch inside diameter. Stainless steel flanges 1/2 inch thick and 12 inches in diameter are welded to the shaft as mountings for the cable drum flanges. The drum flanges are of sandwich construction for strength purposes. Two 60 inch diameter, 1/4 inch aluminum plates are riveted to each side of a 20 inch diameter, 1/2 inch plate. One of the 1/4 inch plates was spun into a slight conical shape and the two 1/4 inch plates were welded at the periphery. A ring of 39-1/2 inch O.D., 37 inch I.D., and 3/4 inch thickness was bolted concentrically to the straight side of each flange to serve as the mounting ring for the drum barrel. The barrel consists of two 1/4 inch aluminum plates each rolled to a semi-circle with an inside diameter of 39-1/2 inches. The two half circles are mounted to the barrel mounting rings with 10-24 flat head machine screws. For additional barrel stiffness a 3/4 inch x 3/4 inch stainless steel ring is mounted inside the barrel midway between the two flanges. The drive chain sprocket is mounted on aluminum stand-offs on the outer side of one of the flanges.

In order to facilitate removal and replacement of the storage drum onto the base, each drum is equipped with bearings and housings. The housings have a machined groove on the outside which mates with a tongue in the housing support and insures proper alignment of the drum in the drum support legs, and prevents side movements of the drum during operation. Figure 1 presents a view of the storage drum with 1/2 of the barrel removed. In addition to the components discussed, the figure also shows the drum to cable connector housing. The connector housing consists of a rectangular stainless steel box with a half tube base which mounts over a wiring exit hole in the hollow shaft. The rear panel of the housing is removable for easy access, and the connector components insert into a ring flange which is so positioned that the cable exits from the drum tangent to the drum barrel at the reel flange. "O" ring and gasket seals make the connector unit essentially watertight.

An additional component of the cable storage drum is the slip ring unit which includes an instrumentation package and 3 power slip rings. The instrumentation package is an enclosed 50 circuit unit No. 17256, manufactured by the Electro-Tec Corporation of Blacksburg, Virginia. The unit is rigidly mounted to the power circuit brush holder ring and is connected to the rotating drum shaft by means of a brass bellows which allows considerable misalignment without stressing the slip ring components.

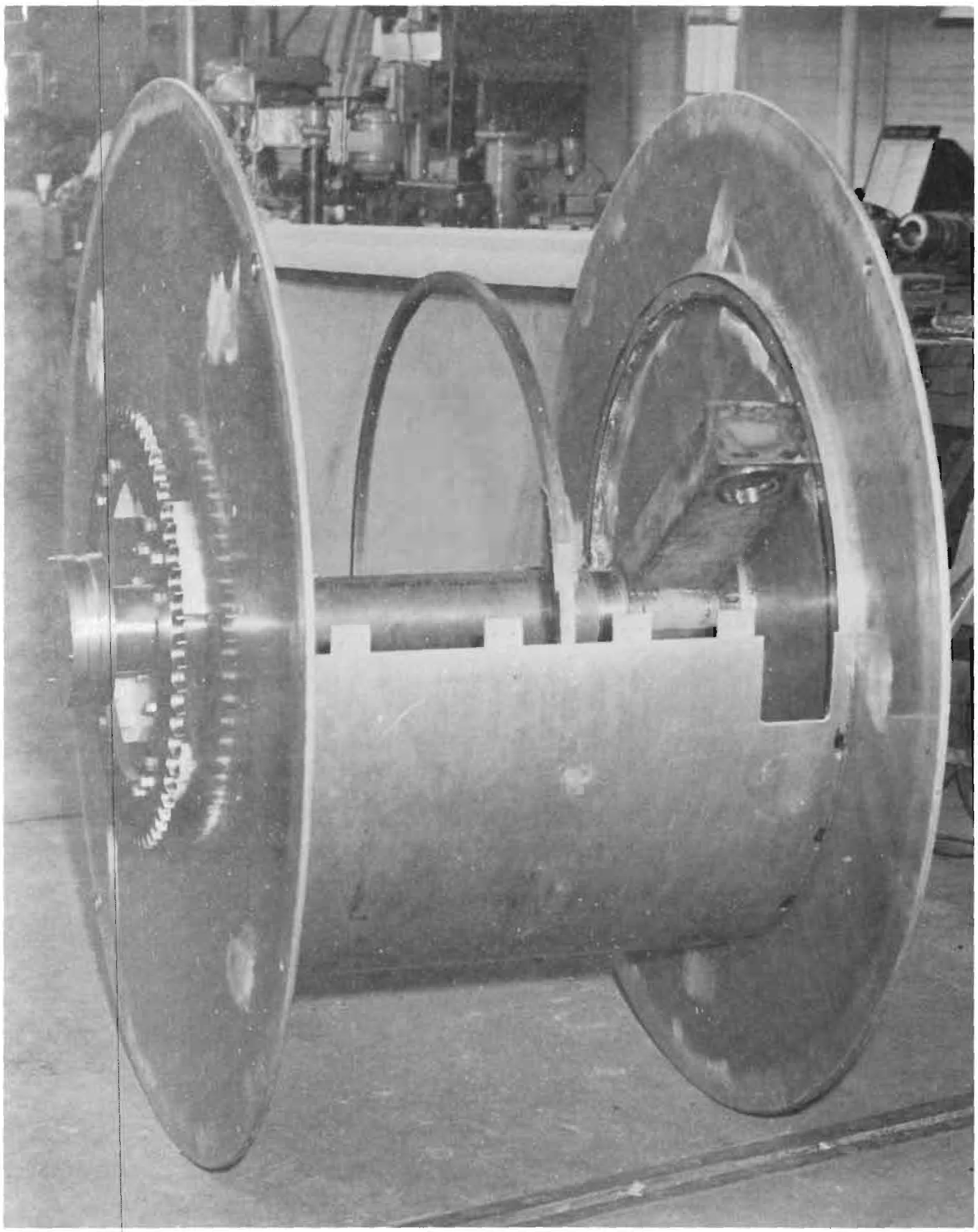

Figure 1. Cable Storage Drum.

Terminal boards are provided for external wiring connections. Figure 2 shows the instrument slip ring mounted into the bellows and power brush holder ring. Figure 2 also presents a view of the power slip ring and brush circuit. The slip ring was manufactured by Georgia Tech since plate type units capable of carrying 40 amps at 2000 volts are not standard with industrial manufacturers. The unit consists of three electrolytic tough pitch copper rings set into M-666 epoxy resin. The rings are separated from each other by 3/8 inch of resin and are inset 1/2 inch into the resin. In order to prevent surface conductance, the 3/8 inch separators are grooved 1/8 inch by 1/2 inch deep so that a minimum surface distance of 2-3/8 inches exists between rings. The brushes are standard copper-carbon brushes modified slightly to fit into the annular ring spaces and are held by brush holders which were changed to accommodate the modified brush. The brush holders are mounted on adjustable aluminum rods and are insulated from the rods by nylon tubes of 1/16 inch wall thickness. Suitable connections are brought out from each slip ring so as to be easily accessible. The slip ring is fixed to a 1/4 inch stainless steel plate by means of the M-666 epoxy and the plate is, in turn, mounted and keyed to the rotating drum shaft. The brush holder rods are mounted through a stand-off ring to the drum bearing housing plate. The slip ring-brush assembly is housed in a water-proof container which has a removable inspection plate. Figure 3 presents another photograph of the slip rings and brushes in position on the drum shaft.

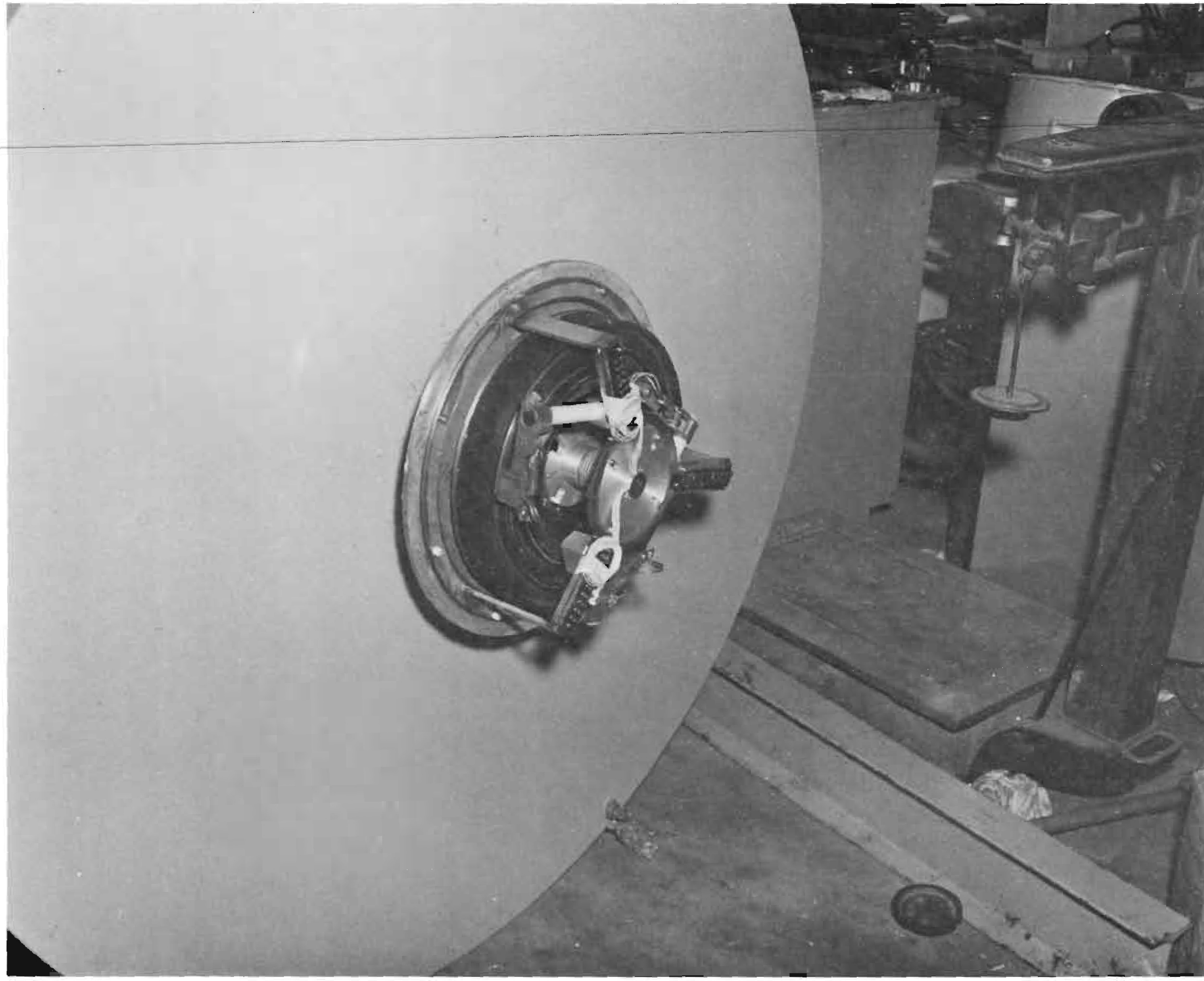

Figure 2. View of Slip Ring Assembly Showing Method of Mounting Instrument and Power Slip Rings.

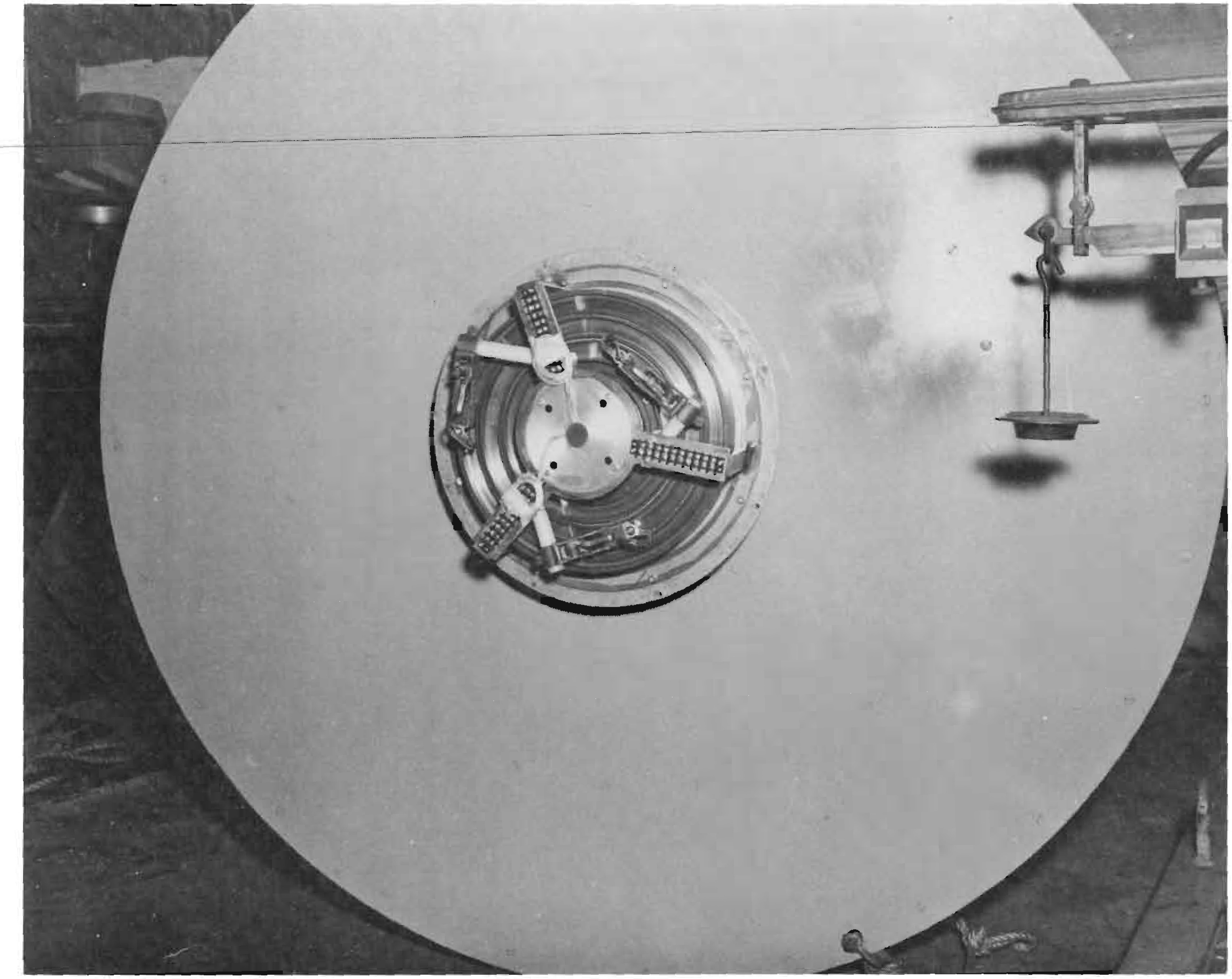

Figure 3. View of Power Slip Rings and Brushes.

2. Base

A single base was designed and constructed to serve as the cable drum receptacle and mounting base for allied equipment. In order to maintain minimum weight commensurate with strength requirements, aluminum tubing and I beams were used exclusively. The base side runners were constructed of 2 inch by 6 inch channels welded together to form 4 inch by 6 inch rectangular tubes. Four cross members of 2 inch by 5 inch by 1/8 inch rectangular tubing were used, three of which were spaced so as to be directly under the drum side support legs. These members were welded into slots cut into the side runners.

Since a three legged truss construction utilized for the drum side support legs insured adequate in line strength of the structure, the design criteria for side support member selection was side force. The drum and cable assembly will weigh approximately 2000 pounds. Therefore, if it is assumed that the unit is resting on the deck of a ship which is rolling at a frequency of .15 cps through $\pm 30°$ about a center of gravity located 20 feet below deck (the reel system is stable to approximately $30°$ roll), the forces exerted due to acceleration will be

$$F = m\,a$$

$$= \frac{2000}{32.2}\,(\omega^2 x)$$

$$= 62.1 \left[\left(\frac{2\pi}{T}\right)^2 \times 20 \right]$$

$$= 62.1 \left[\left(\frac{6.28}{7}\right)^2 \times 20 \right]$$

$$F = 1000 \text{ pounds}$$

where m = mass of cable-drum assembly

ω = angular velocity of oscillation

x = system displacement, maximum

T = period of oscillation

Superposed on this acceleration force must be the component of the weight which acts in the side direction because of the 30° list angle. This weight force is

$$F = 2000 \tan 30^\circ$$

$$F = 1120 \text{ pounds}$$

Thus, the total force acting sideways on the support member is

$$T_{t_s} = 1000 + 1120 = 2120 \text{ pounds}$$

In order to prevent exceeding the yield point of the side members (6061-T6 aluminum with a yield strength of 28,000 psi) the side support moment of inertia must be

$$I = \frac{Mc}{S}$$

$$I = \frac{2120 \times 31 \times 1.5}{28}$$

$$I = 3.6 \text{ in}^4$$

where I = moment of inertia of supports

M = maximum moment, weight x support length

c = support neutral axis (for 3" width = 1.5 in)

S = yield strength of support material

Because of the rigidity of the drum shaft and the tongue and groove construction of the bearing housing supports, the force can be safely assumed to be carried equally by the two side supports. This, considering three members per side of 2 inch by 3 inch by 1/8 inch aluminum tubing, the stress in each member becomes

$$S = \frac{Mc}{I}$$

$$S = \frac{2120 \times 31 \times 1.5}{6\left(\frac{b_1 h_1^3}{12} - \frac{b_2 h_2^3}{12}\right)}$$

$$S = 11{,}250 \text{ psi}$$

where b_1 = outside width of tubing, 2 inches

h_1 = outside depth of tubing, 3 inches

b_2 = inside width of tubing, 1.75 inches

b_2 = inside depth of tubing, 2.75 inches

This construction affords a safety factor of 2.5 for a condition which is believed to be somewhat worse than will be experienced.

Because the greatest stress will occur at the juncture of the side supports with the base, the side supports are inserted through the side runners of the base and the cross members, such that welds could be obtained to both the side runners and the cross members.

Figure 4 is a photograph of the assembled base with the side supports welded into place. The drum bearing housing mounts are shown fixed to the side supports. The drum positioning tongue and the mounting holes for the mating

Figure 4. Base Assembly.

housing mount caps can be seen. Also shown are four stainless steel pick-up eyes located at the corners of the base as well as the control panel mounting beam which is welded to the side support. The I beams shown in the figure form the mounting surface for the drive system and cooling unit mounting plates. Figure 5 presents a view of the system component placement.

B. Hydraulic

1. Motor, Pump and Reservoir

The horsepower requirements for the hydraulic unit are quite small, i.e., 1.82; however, the requirement for 500 pounds of cable tension at a recovery speed of 1 ft/sec actually determines the size of the system. If it is assumed that this force is exerted at the center of the top layer of cable, the torque requirements become 2.36 (500) or 1180 foot-pounds. In order to meet this requirement, a Webster Wisconsin SM200 gear motor capable of 1000 inch-pounds of static torque at 1500 psi was selected. It was estimated that the 15:1 worm gear reducer and the 2:1 chain drive would be 85% efficient; thus the static output torque at the reel would be approximately 1230 foot-pounds. The motor was matched to an S 200 Webster Wisconsin, electric motor driven pump which supplies the motor requirements of 24 gpm at 1500 psi. The input power required for the pump under these conditions is 20 horsepower.

Because of space limitations, the hydraulic pump, drive motor, and reservoir were constructed as a single unit. The motor was vertically mounted to the top of a five gallon reservoir with the pump and a flexible

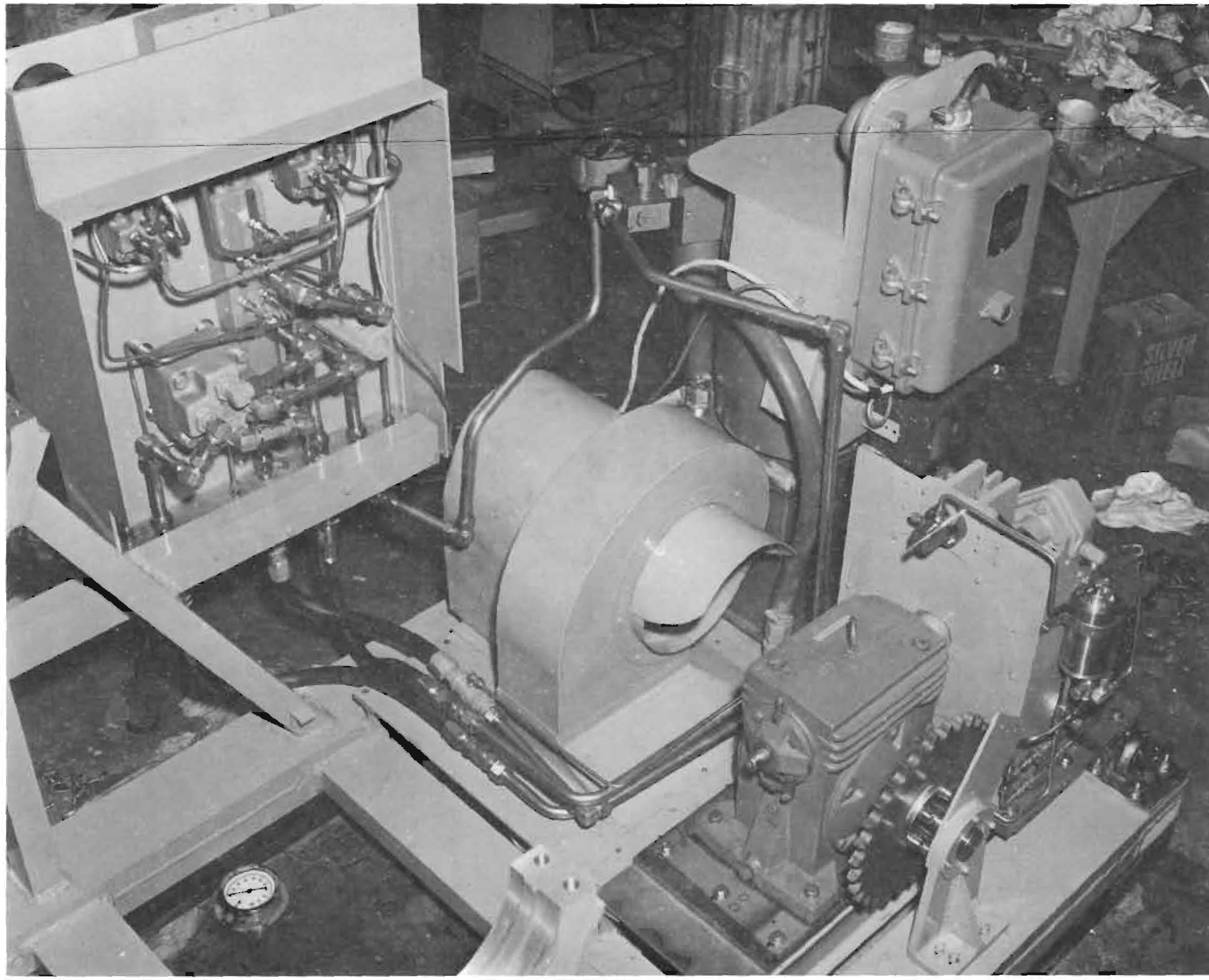

Figure 5. View of System Component Placement.

coupling located inside the reservoir. The output of the pump passes directly through a 10 micron high pressure Purolator filter which is located immediately adjacent to the pump-reservoir. A pressure bypass valve is located immediately down stream of the filter.

2. Controls

All control equipment is located on the control panel which is mounted to the right side support of the reel. Figure 6 shows a front view of the control panel. The large valve shown in the picture is a 3/4 inch P4630VPCD Weatherhead four way valve used for control of the reel motor. The two small valves are 3/8 inch P4630VP Weatherhead, four way valves provided for control of the two remote hydraulic motors. These are manual valves and operate on the principle of connecting motor lines to pressure or return depending upon the direction of rotation of the valve face. Proportional or speed control is obtained according to the amount of rotation of the face.

All hydraulic lines to and from the control panel are flexible hoses equipped with quick disconnects with the exception of the primary pressure and return lines. These lines terminate at the bottom of the panel with swivel type connectors.

Because of the numerous secondary pressure and return lines involved in the system, pressure and return reservoirs were constructed by drilling two 3/4 inch holes side by side and longitudinally through a 2 inch by 3 inch by 15 inch aluminum bar. This bar is mounted to the rear of the control panel and the primary pressure and return lines are connected to the pressure

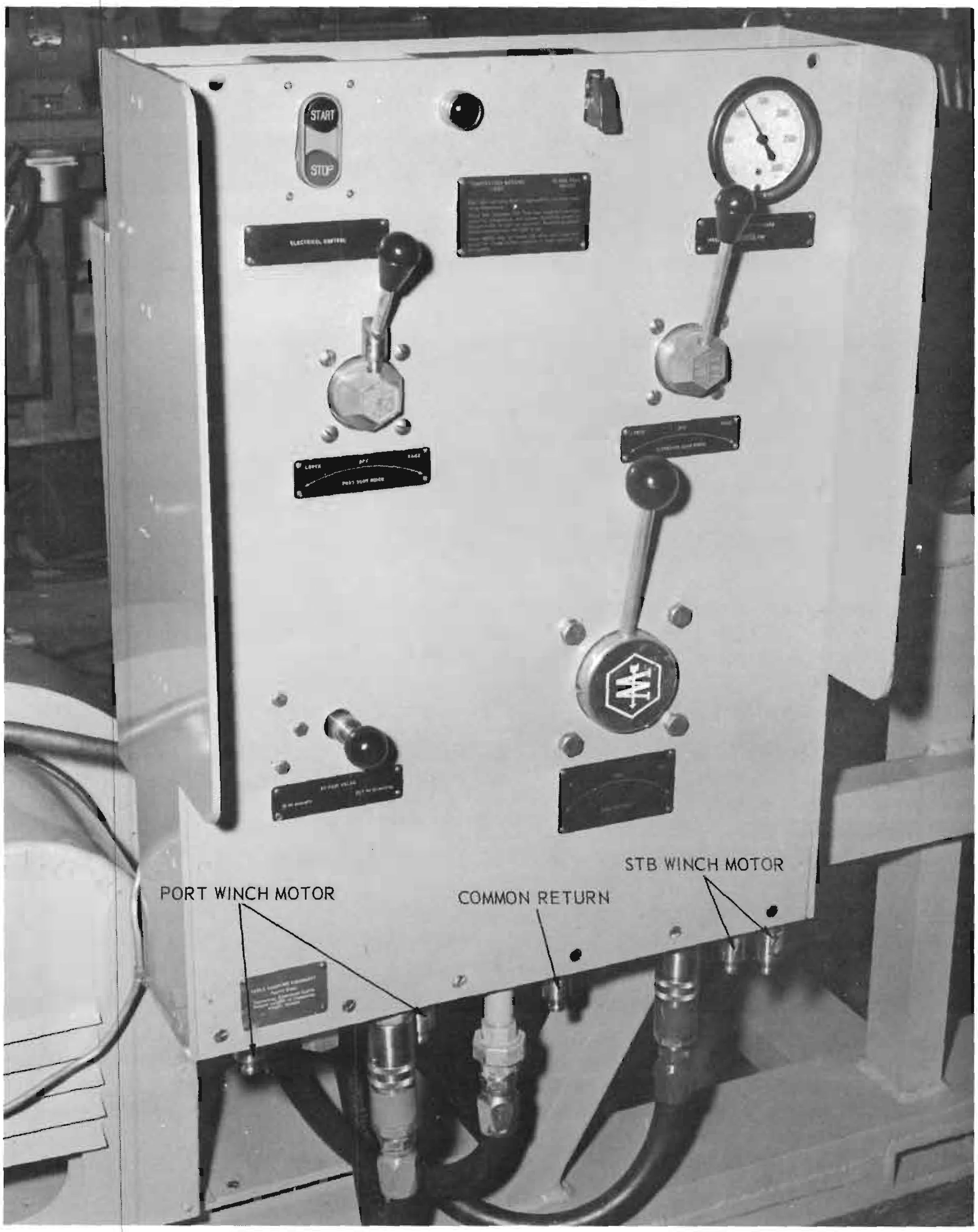

Figure 6. Front View of Control Panel.

and return sides of the resulting reservoir bar. All secondary pressure and return lines are connected into the proper longitudinal hole in the bar. Figure 7 is a photograph of the rear of the control panel showing the reservoir bar, hydraulic tubing, and control valves. Figures 6 and 7 also show the by-pass valve used to off load the system when pressure is unnecessary. The valve is an 824-11, 3/4 inch, Manitrol selector valve which operates on the push-pull principle. The normal operating mode of the valve is pushed in. Also shown in Figure 6 are the remote winch motor hydraulic take-off points.

3. Cooling

Under conditions of normal reel operation there should be no problem with overheating of the hydraulic fluid. However, when the system is pressurized and by-passing through the pressure relief valve, the entire electric drive motor input must then be used in generation of heat since no useful work is being done. Considerable heat will probably also be generated when the small remote motors are operated (assuming that the reel motor is idle) since only a small portion of the fluid output can be utilized. Under the former (and worst) condition, approximately 50,000 B. T. U. per hour will be generated by the action of the pump on the fluid. Since the entire system contains approximately 8 gallons of fluid, it is readily seen that extremely high fluid temperatures would result in a very short time.

In order to alleviate this situation as much as possible, a fluid cooling system consisting of a 2000 ft^3/min centrifugel blower and a Ford Falcon

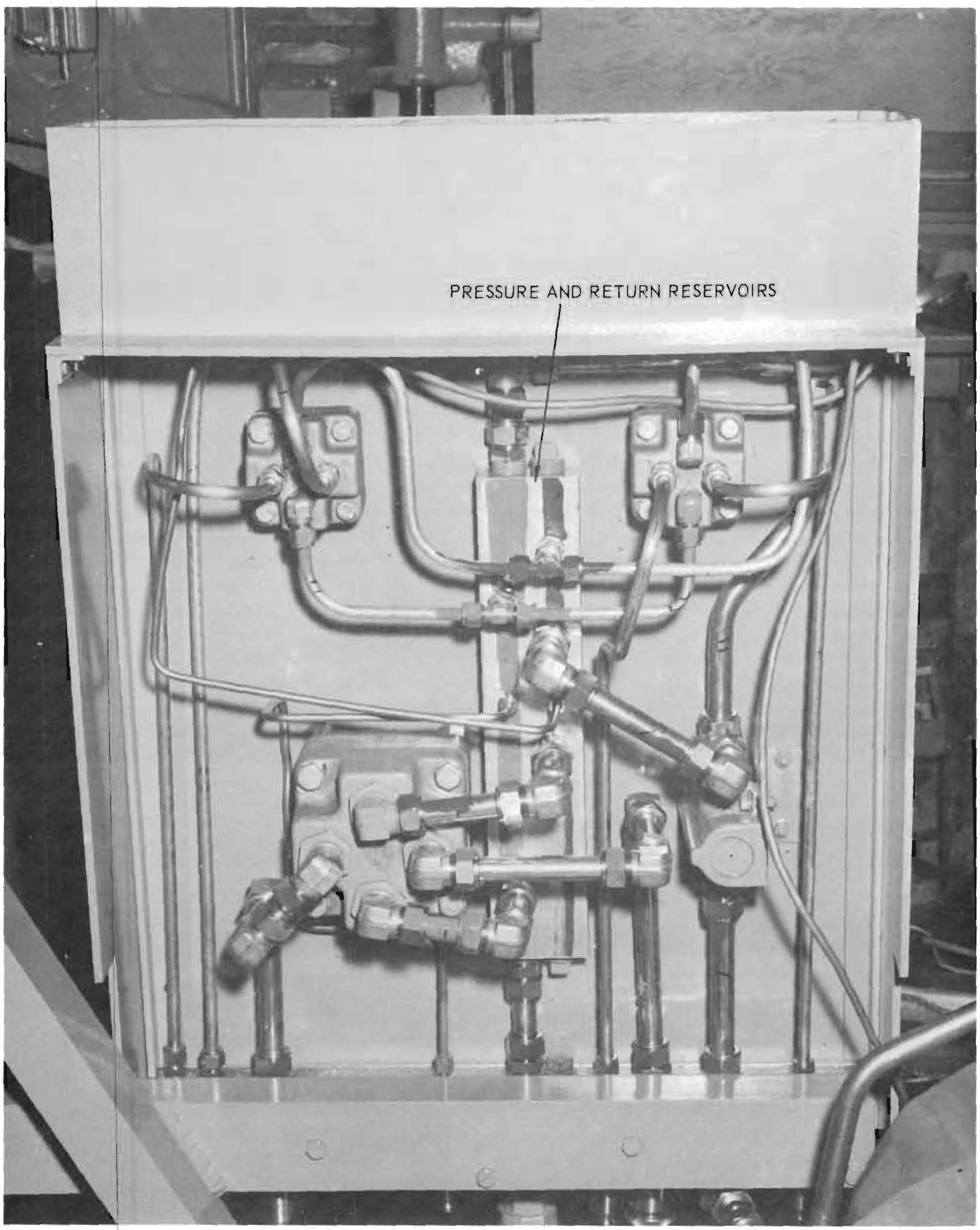

Figure 7. Rear View of Control Panel.

radiator, modified so as to force the fluid to travel the length of the radiator three times, was installed.

The radiator was mounted on one side of a 1/4 inch thick aluminum plate and the blower (with appropriate ducting) was mounted to the opposite side in such a manner as to force all the air through the radiator fins. The assembled unit is mounted to the reel base and all fluid returning to the main reservoir is routed through the cooling system. Figures 8 through 10 present various views of the cooling system.

Tests of the cooling unit showed that approximately 30,000 B.T.U/hr can be dissipated at a fluid temperature of 180°F. It was also found that cooling was limited by the inside or hydraulic fluid convection coefficient rather than the air coefficient. An effort was made to improve the rate of heat transfer by increasing the fluid velocity; however, this resulted in pressure drops through the radiator which were prohibitive from a stress standpoint as well as proper control valve operation. Both the hydraulic fluid and the seals in the system have operating temperatures up to 250°F. The cooling unit cannot maintain even this temperature under complete pressure by-pass conditions; however, such conditions should seldom exist and it is believed that excessive temperatures will not be a problem during normal operation. Figure 11 presents a hydraulic diagram of the complete system.

C. Electrical

The electrical portion of the hydraulic system consists of a 20 hp, 440 volt, three phase pump drive motor, a 1-1/2 hp, 440 volt, three phase blower drive motor, a 25 hp magnetic starter, and a stop-start switch. The

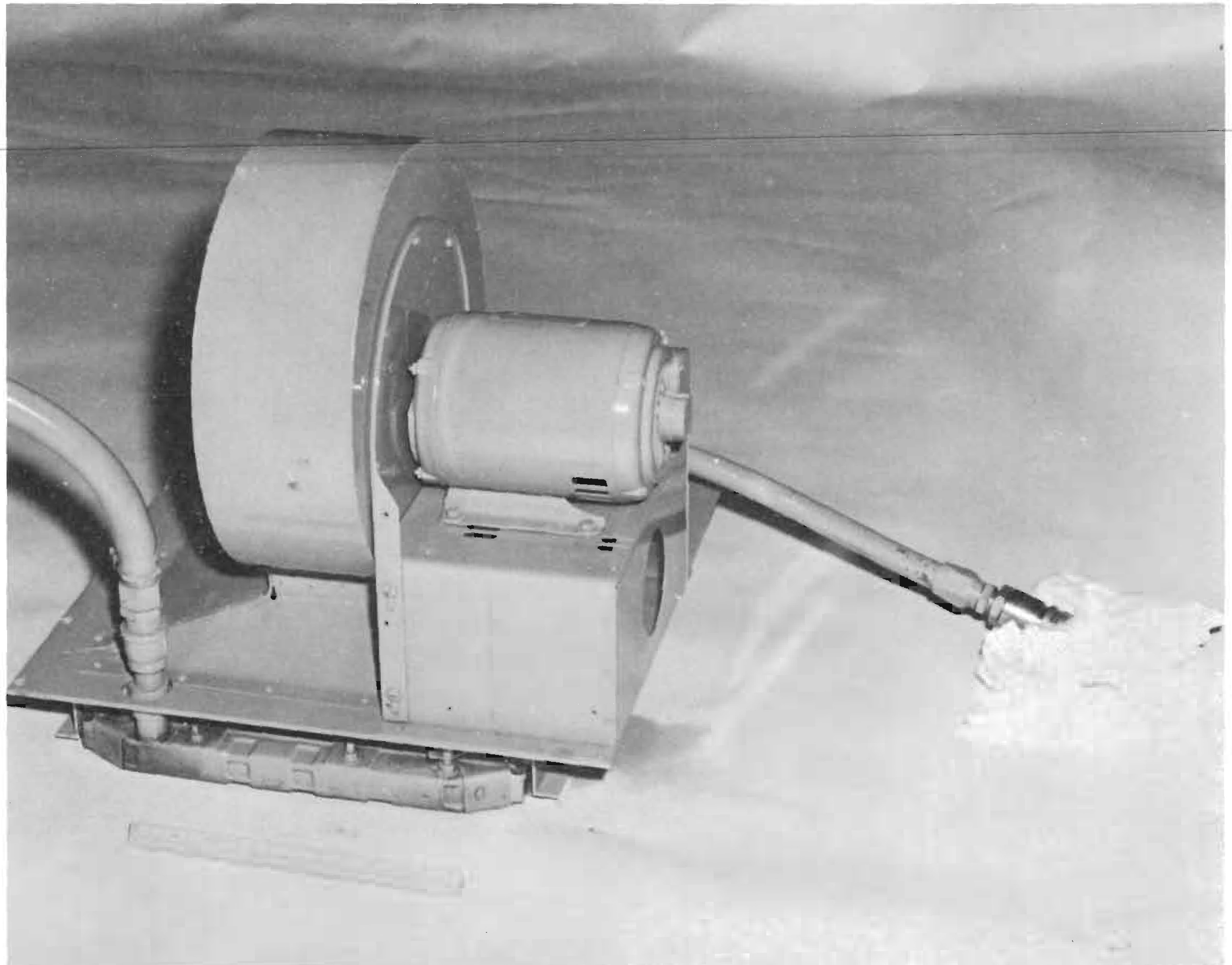

Figure 8. Side View of Cooling System.

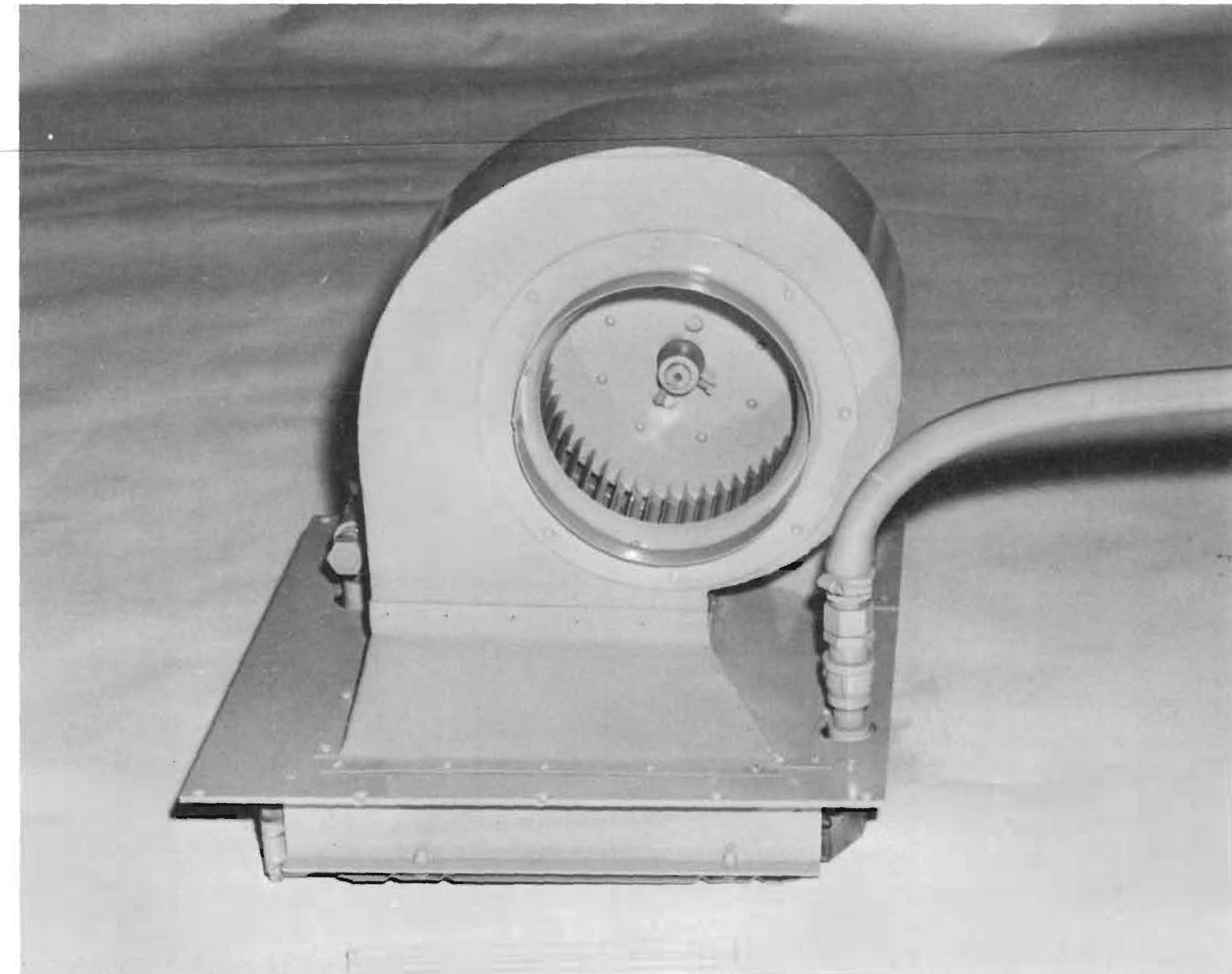

Figure 9. Side View of Cooling System.

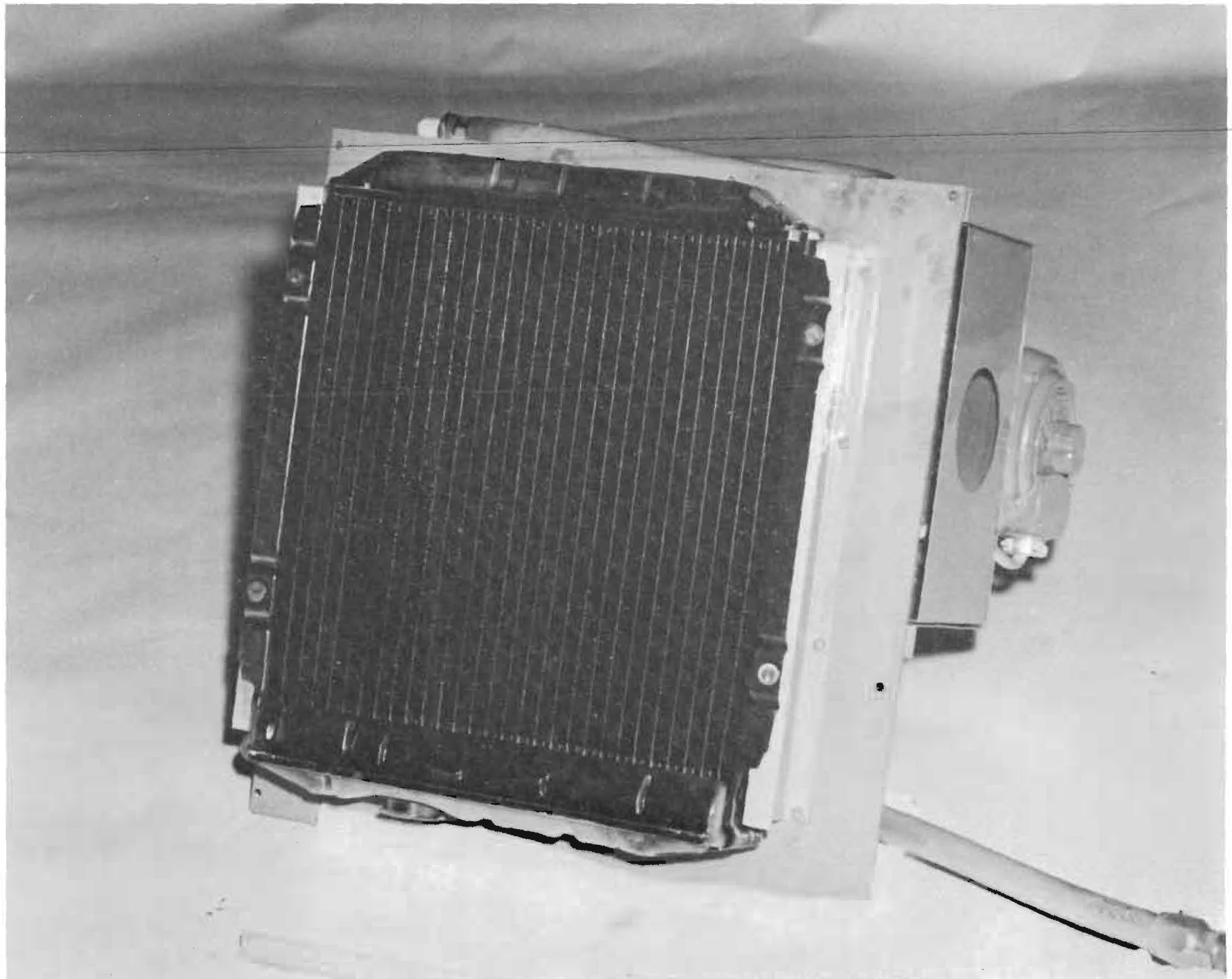

Figure 10. Bottom View of Cooling System.

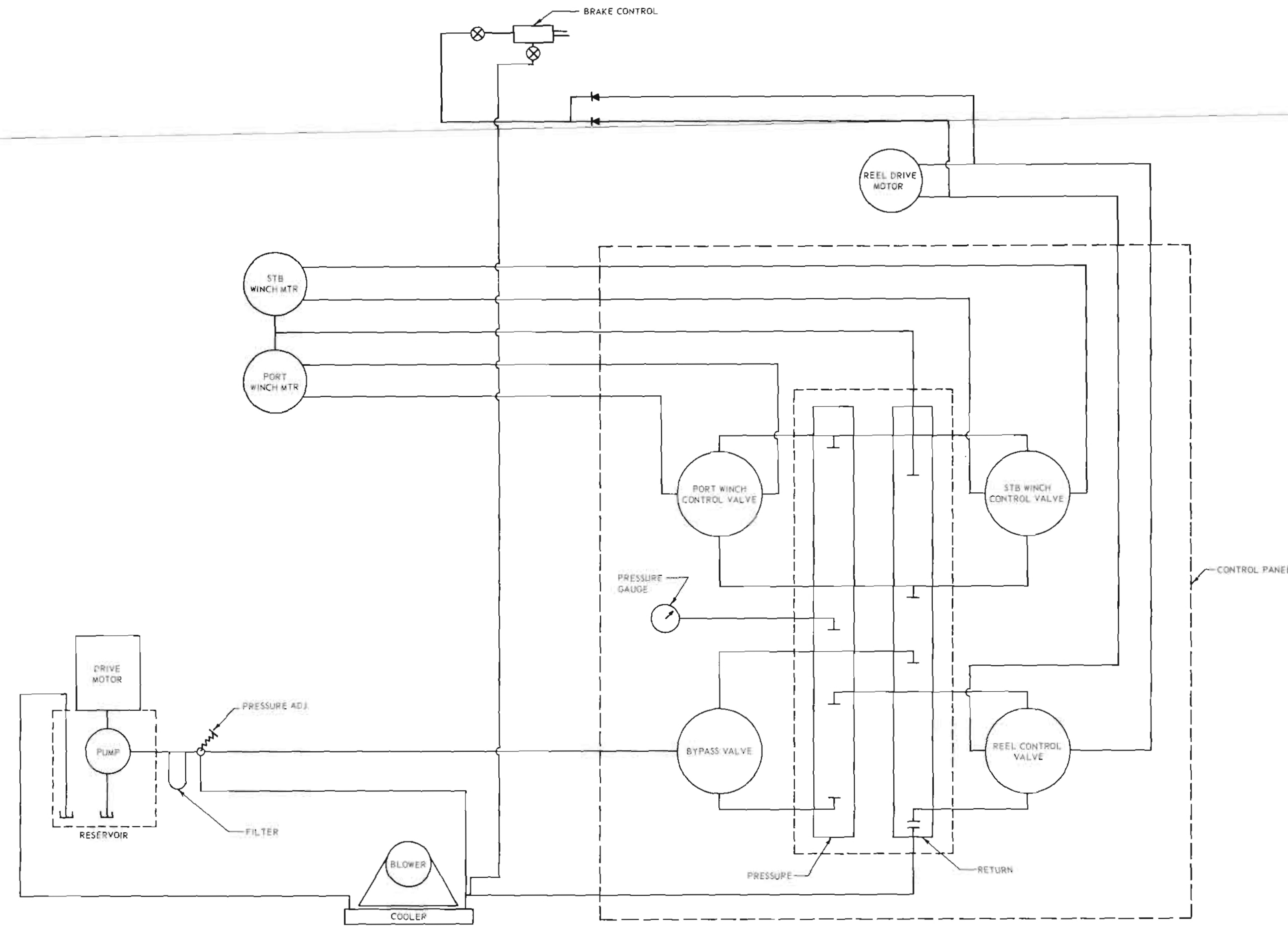

Figure 11. Hydraulic Diagram.

motors and magnetic starter are mounted to the reel base and the stop-start switch is located on the control panel. The two motors are parallel wired from the magnetic starter and are simultaneously controlled by the stop-start switch.

In order to prevent carrying the 440 volt current to the control panel, a 110 volt holding coil was installed in the magnetic starter. A 4:1 stepdown transformer between two phases of the 440 volts furnishes the 110 volt current to the holding coil. Figure 12 shows the magnetic starter and the transformer mounted in position. Figure 13 presents a wiring diagram for the system.

The magnetic starter, transformer, and switch are sealed units. The two motors have been sufficiently enclosed to insure that they are splash proof.

D. Protective Devices

1. Temperature Warnings

Two means of fluid temperature rise warning have been provided, a red light and buzzer which come on at 195°F and an alarm bell which sounds at 240°F. Both warning devices are controlled by Fenwal normally open thermoswitches which are mounted to the main reservoir such that the switches are always submerged in the fluid. When the hydraulic fluid temperature reaches the preset levels, the contacts of the switches close and activate the warning devices. Power for the warning devices is obtained from the 110 volt transformer. Figure 12 also shows the location of the thermoswitches.

Two warning devices were used because of the nature of system use. It is possible that with a single maximum temperature device a procedure might be in process which necessitated the continued use of the equipment for a considerable period of time, thus causing drastic overheating of the fluid.

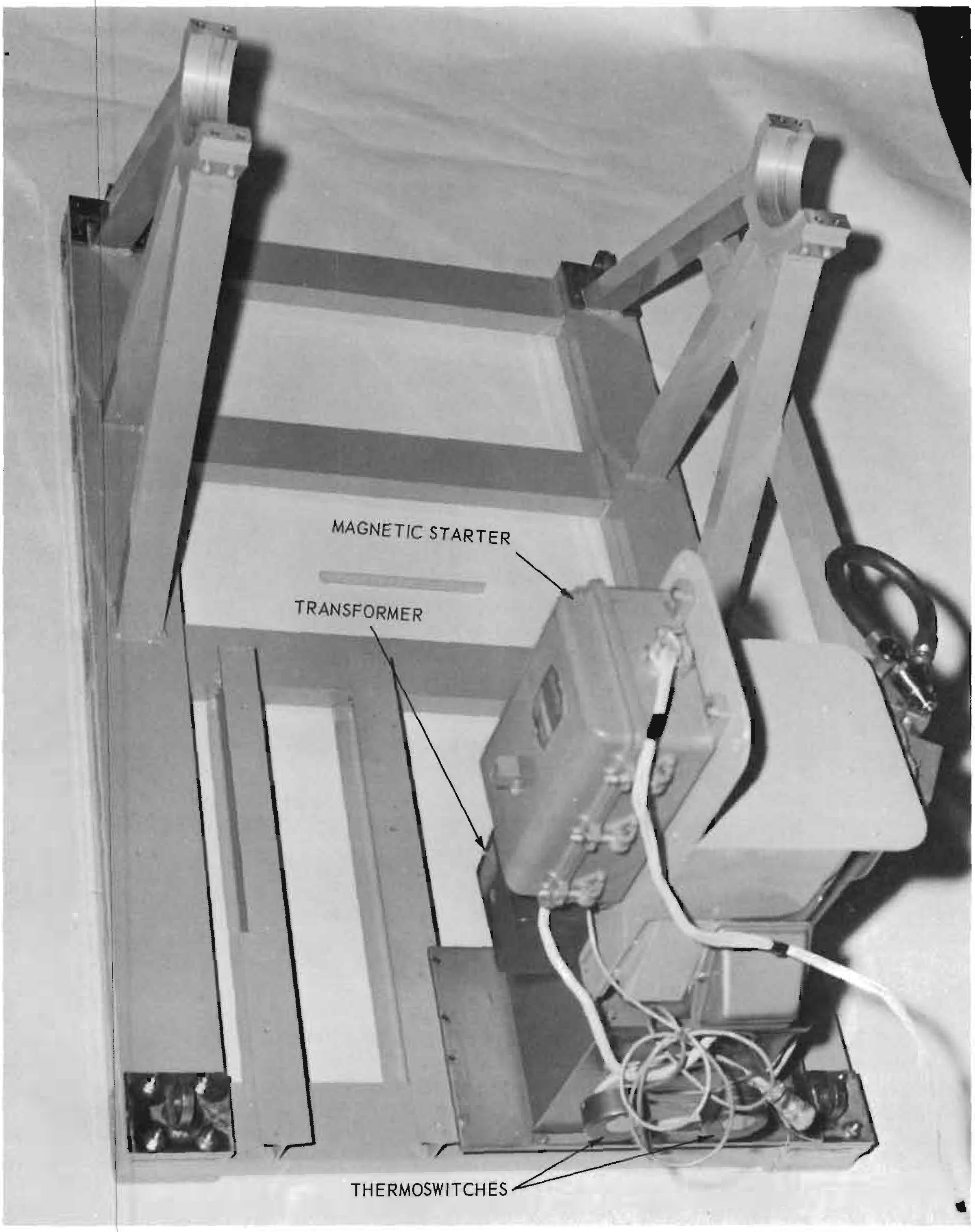

Figure 12. View of Base Showing Electric Drive Motor, Hydraulic Reservoir Magnetic Starter, Transformer, and Thermoswitches.

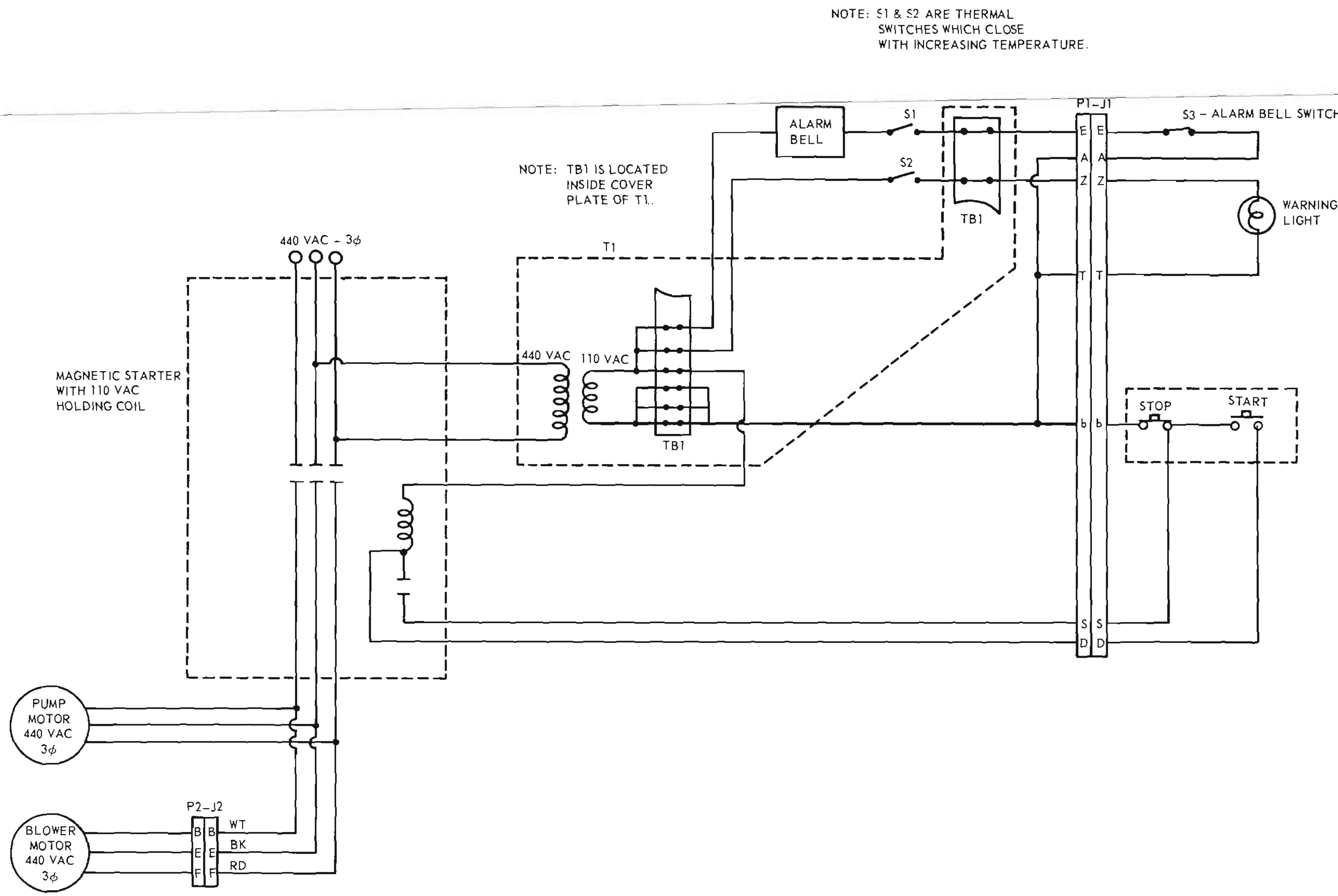

Figure 13. Wiring Diagram.

However, with the additional early warning device, it becomes possible to utilize planned break periods during which the hydraulic system can be placed in the zero pressure by-pass mode and rapidly cooled to an acceptable temperature.

2. Fail-safe Brake

The fail-safe brake consists of a hydraulically operated cylinder which, when pressurized, operates a lever which depresses the springs of a standard automotive pressure plate and releases a disc brake. The pressure plate is mounted to a stainless steel fixture which, in turn, is mounted to the reel base. An extension to the input shaft of the worm gear reducer includes a brake flange to which a standard clutch facing is attached. When the cylinder is unpressurized the pressure plate spring pressure is sufficient to effectively lock the reducer input shaft up to a torque of some 200 foot-pounds.

The hydraulic cylinder is connected to both lines leading to the reel motor, and check valves are provided to prevent cross flow. A connection is also supplied from the cylinder to the system return for the pressure bleed-off when the reel motor is not operating. The rapidity of braking action is governed by a needle valve located in the return line. If this valve is opened more than approximately one revolution of the handle, the brake will not release, since there is insufficient pressure build-up in the cylinder. If the valve is not opened enough, the brake will be slow to set when the pressure is removed from the cylinder. Experience has shown that the valve should be opened approximately 225 degrees of handle revolution for best operation. It should be noted that some time lag will occur between the removal of pressure from the cylinder and the setting of the brake. If recovery under tension is in progress at the time of pressure removal, some unwinding of the reel will occur; however, this should never amount to more than a few feet of cable, and is necessary to prevent extreme shock loads on the drive system.

A method for manually releasing the brake is also provided in the event that free wheeling of the reel becomes necessary without system pressure. The brake may also be held in the released position hydraulically if desired. This is accomplished by closing the cylinder-to-return needle valve and pressurizing the cylinder by very slightly opening the reel control valve. The cylinder pressure is held by check valves in the cylinder pressure lines. Normal braking action is regained by opening the return needle valve the prescribed amount.

Reduction in the holding torque of the brake caused by facing wear can be compensated by moving the pressure plate fixture assembly closer to the brake flange. Slotted bolt holes are provided in the fixture for this purpose. Figure 14 presents a build-up of the brake components.

E. System Size and Weight

The dimensional envelope of the system is 53 inches wide, 41 inches long, and 65 inches high. The weight, including 1400 feet of cable is approximately 3700 pounds. Figures 15 and 16 are photographs of the complete unit including cable.

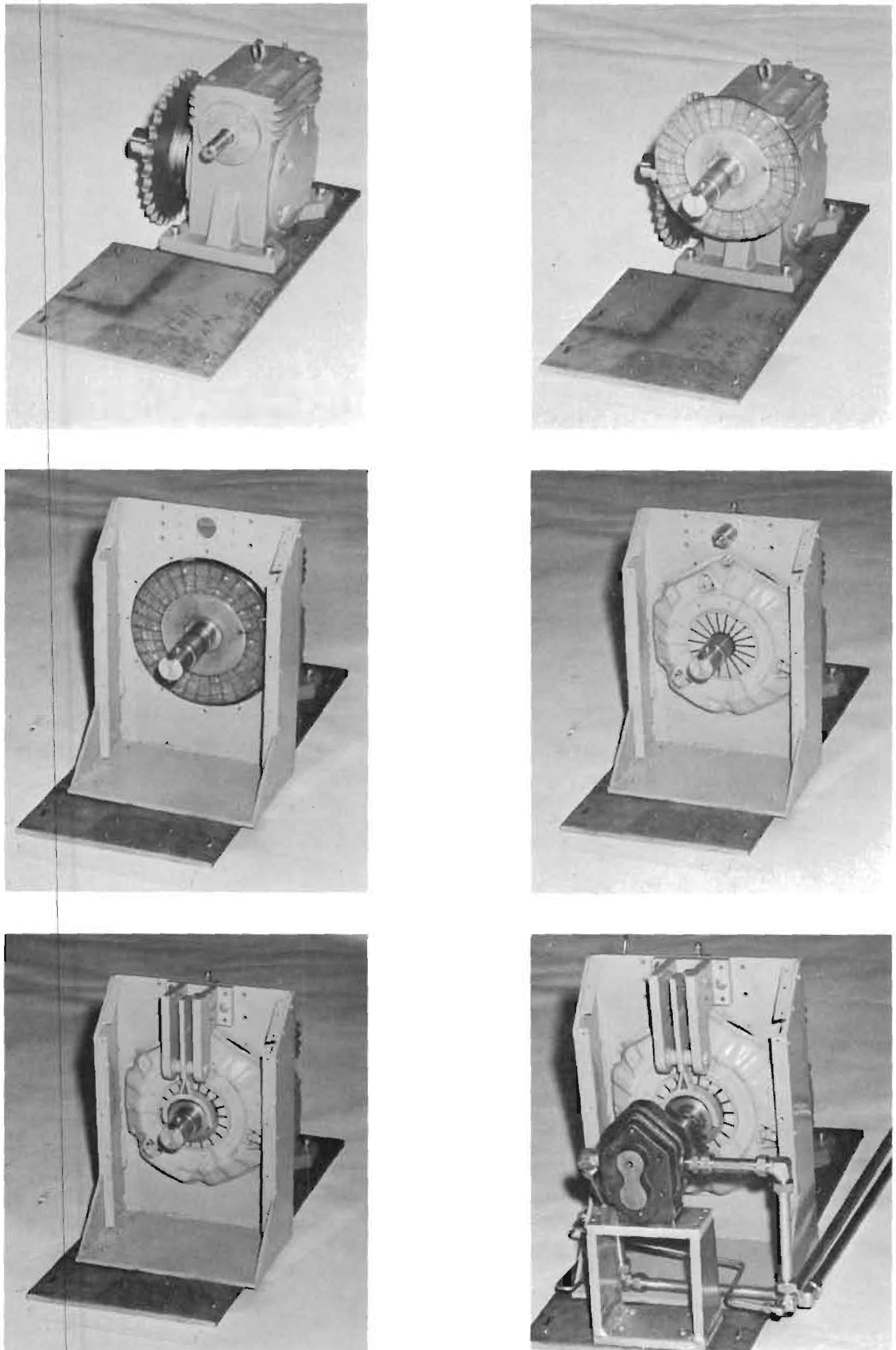

Figure 14. Brake System Build-up.

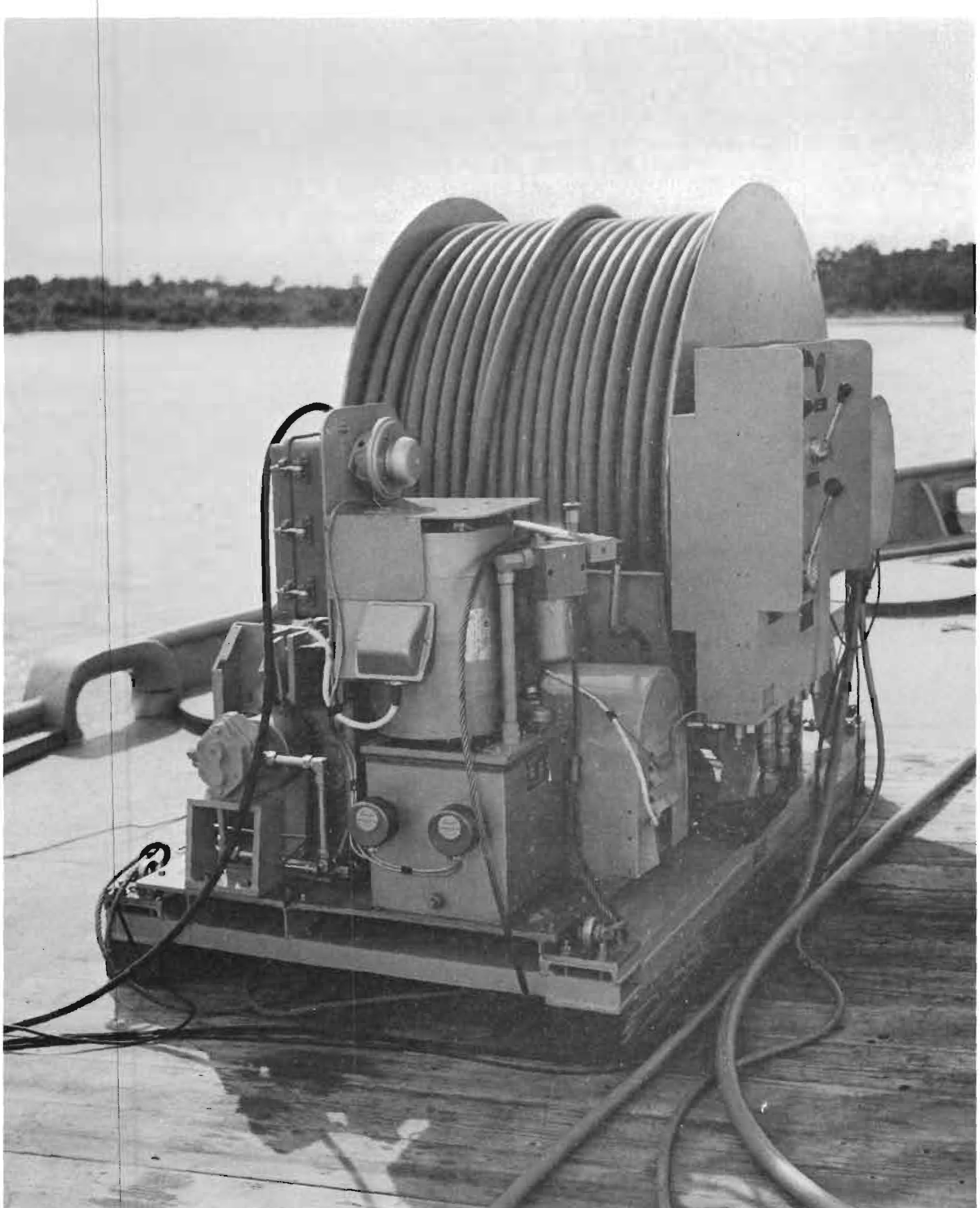

Figure 15. Rear View of Cable Handling Equipment.

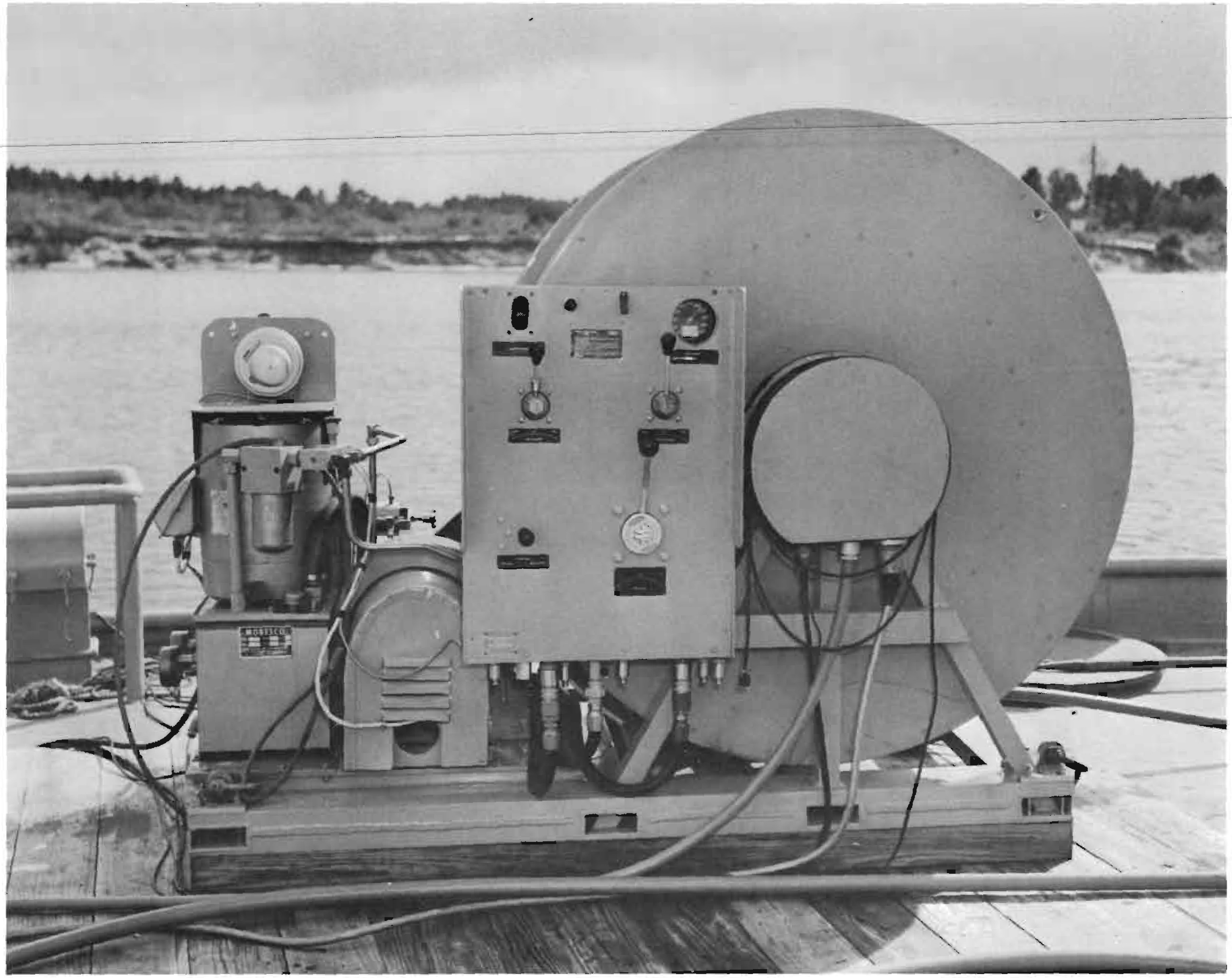

Figure 16. Side View of Cable Handling Equipment.

V. EQUIPMENT TEST

As much testing as possible was conducted at Georgia Tech prior to delivery of the unit. As discussed previously, the cooling system was thoroughly checked out and is believed to be adequate. The fail-safe brake was also checked up to a reel torque of 5500 foot-pounds which was the limit of the tensiometer available. No slippage had occurred at this point and it is believed that the brake will hold a reel torque of 6000 foot-pounds.

The static torque delivered to the reel by the motor was found to be 1250 foot-pounds which should be sufficient to meet the requirement of a one ft/sec recovery rate at 500 pounds cable tension. Reel speed control was found to be quite smooth throughout the range of 0 to 42 rpm although somewhat critical as to valve movement.

No dynamic loading tests were possible at Georgia Tech. These tests will be accomplished under operating conditions at NAVMINDEFLAB and will determine the actual usefulness of the system.

VI. OPERATING AND MAINTENANCE PROCEDURES

The following section contains operating and maintenance instructions pertaining to the hydraulic reel and winch drive system constructed by Georgia Tech for NAVMINDEFLAB.

A. Start up

1. Ground the unit electrically.
2. Check fluid level in reservoir.
3. Place system in by-pass mode.
4. Press start button.
5. Place system in operate mode by pushing in the handle to the selector valve and check pressure level. Pressure may drop slightly as temperature increases; however, pre-set relief valve should not be changed to compensate. If desired, the system pressure can be changed by resetting the pressure relief valve. This is a Manitrol RP-1200 valve located immediately downstream of the filter. Settings are changed by lifting the handle and rotating counterclockwise for pressure decrease and clockwise for pressure increase. UNDER NO CIRCUMSTANCES SHOULD THE SYSTEM PRESSURE BE SET TO EXCEED 1500 PSI SINCE THE ELECTRIC DRIVE MOTOR WILL BECOME OVERLOADED.
6. Be sure that the valves located in the pressure and return lines of the brake cylinder are open. Pressure valve should be completely open and return valve should be open approximately 225° of handle revolution.

7. Open reel control valve slightly and check to see that brake releases properly.

8. If brake releases properly, close reel control valve to be sure brake again sets properly. Brake will require from 1 to 2 seconds to set after reel control valve is closed.

   Note: It is important to assure that the reel control valve is completely closed. The valve has a detent at the center or closed position. If the valve handle is off the detent position in either direction, the brake will not set.

9. If the hydraulic brake valve is actuating properly and the brake does not have sufficient holding torque, adjustments of the brakes should be checked. The procedure for accomplishing this is outlined under the sub-heading, "Maintenance."

B. Temperature

The system will heat quite rapidly when in the pressure mode and when fluid is not being used. The cooling system is inadequate to maintain a safe temperature level under these conditions. Under ordinary operating conditions, overheating should not be a problem. There are two temperature warning devices, a red light which comes on and a buzzer which sounds at a temperature approaching 200°F, and an alarm bell which sounds at 240°F. When the alarm bell sounds, the system should be placed in the by-pass mode as soon as practical and allowed to cool until the red light and the buzzer go off (approximately 3 minutes). Normal operation may then proceed.

C. Shut-down

Prior to shut-down, system should be placed in by-pass mode and allowed to cool for approximately 5 minutes before depressing drive motor stop switch.

D. Brake release

There are two methods of continuously holding the brake in the release position. In the event that hydraulic pressure is available, the brake return valve may be closed and the brake cylinder actuated by very slightly opening the reel control valve. The brake will then be hydraulically held in the released position until the return valve is again opened. If hydraulic pressure is not available, the brake may be manually released by screwing in the 1/2-inch bolt affixed to the rear of the hydraulic cylinder. The bolt drives the cylinder piston to the brake release position. Under either of the above conditions, the brake will remain released until it is returned to the normal operating position by either opening the return valve or screwing out of the 1/2-inch brake release bolt.

E. Lubrication

Bearings used in the cable storage drums are prelubricated with Andoc C Lubricant and semi-sealed. No additional lubrication should be necessary for the life of the equipment. The worm gear reducer requires SAE 90 or 600 w lubricant and should be filled according to instructions which accompany the unit.

F. Cable drum replacement

To replace the cable drum with the spare drum, the following procedure should be followed.

1. Remove external electrical wiring.

2. Remove the chain guard.

3. Disconnect the drive chain. The disconnect link in the drive chain can be identified by the short, smaller cotter pins used to hold the link in place.

4. Remove the bearing housing retaining caps. These caps are located on top of the reel base side supports and are secured by 4, 1/2-inch bolts in each cap.

5. Remove the drum by lifting up sufficiently for the drum bearing housing to clear the housing supports. Lifting eyes are provided in the flanges of the drum.

6. Install the new drum by reversing the above procedure.

   Note: When placing the new drum in the supports, care should be taken to insure that the electrical connectors of the slip ring housing are in a downward position.

G. Drive chain tension

Drive chain tension may be increased or decreased by loosening 8, 3/8-inch bolts which secure the 1/2-inch reducer mounting plate to the 1/4-inch base plate and sliding the mounting plate to the rear or forward respectively. The 3/8-inch mounting plate holes are slotted to allow sufficient movement for adjustment.

H. Maintenance

1. Filter

The system is equipped with a high pressure, 10 micron filter which incorporates a visible warning in the form of a red rod which extends from the top of the filter body when the element needs replacement. A replacement element is furnished with the unit.

2. Fluid

The fluid used in the hydraulic system should be Shell Oil Tellus 15. Do not mix fluids. Because the system operates at rather high temperatures, some moisture condensation may occur within the main reservoir. After the first 25 to 50 hours of operation the reservoir should be drained and the fluid examined to determine if moisture is present. If moisture is evident, the system should be flushed and new fluid added. Periodic checks should be made at intervals thereafter. If no moisture is evident after 100 hours of operation, it can be assumed that condensation will not be a problem; however, the fluid should be changed at six months intervals regardless of use.

3. Brake adjustment

Brake adjustment is accomplished in the following manner:

a. Brake should be completely released by screwing in the 3/8 bolt which drives the cylinder piston to the brake release position.

b. Loosen the 6, 3/8-inch bolts and 2, 1/4-inch bolts which screw the pressure plate fixture to the base plate. The holes in the fixture are slotted sufficiently to give adequate longitudinal motion.

c. The fixture is then moved forward until approximately 1/32-inch space remains between the brake facing and the pressure plate and the bolts are tightened. The manual release bolt is then screwed out until free of the piston rod and the procedure is complete.

Note: The brake facing consists of a standard 1960 Chevrolet, 1 ton truck clutch facing. It is attached to the brake flange by means of 5 - 40 flat head machine screws, counter-sunk so as to be at least 1/16-inch under the facing surface. A spare facing is provided with the unit.

4. Temperature warning thermoswitches

The temperature warning thermoswitches should be checked periodically to insure against setting changes. This can be accomplished by operating the system in the pressure by-pass mode and checking the switch closing temperatures by means of a thermometer inserted in the reservoir breather hole. If setting changes become necessary, the thermoswitch covers may be removed and the temperature set screw turned clockwise for higher temperatures and counter clockwise for lower temperatures.

VII. LIST OF PARTS

Quantity	Item	Nomenclature	Vendor
1	Motor	20 HP, 3 phase, 440 volt	Mobesco, Atlanta, Ga.
1	Coupling	20 HP, Magnaloy	Mobesco, Atlanta, Ga.
1	Pump	S 200 Webster-Wisconsin	Mobesco, Atlanta, Ga.
1	Reservoir	Tinamite, 5 F	Mobesco, Atlanta, Ga.
1	Filter	Purolator, P 142-02-2	Mobesco, Atlanta, Ga.
1	Filter Element	Purolator, #63561-2	Mobesco, Atlanta, Ga.
1	Relief Valve	Manitrol, RP-1200	Mobesco, Atlanta, Ga.
1	Selector Valve	Manitorl #824-11	Mobesco, Atlanta, Ga.
2	Thermoswitch	Fenwal Cat. #17823-0	Applebee-Church Co. Atlanta, Ga.
1	Control Valve	Weatherhead, P463VPCD	Mobesco, Atlanta, Ga.
2	Control Valve	Weatherhead, P4330VPCS	Mobesco, Atlanta, Ga.
1	Motor-Blower	#2568, 440V, 1-1/2HP Dayton	W. W. Granger, Inc. Atlanta, Ga.
1	Alarm Bell	#340-22 w/#348 Box(Farraday)	Graybar Electric Co., Atlanta, Ga.
1	Warning Light	Dialco, 75W, 110 volt	Specialty Electric, Atlanta, Ga.
1	Pressure Gage	Helixoid, 3-1/2, type 430L Phenol	Mobesco, Atlanta, Ga.
1	Coupling	Dodge #6020	Owen-Richards Co., Atlanta, Ga.
1	Pressure Plate	1960 Chevrolet, 1 ton truck	John Smith Co., Atlanta, Ga.

Quantity	Item	Nomenclature	Vendor
1	Brake Facing	1960 Chevrolet, 1 ton truck Clutch facing	John Smith Co., Atlanta, Ga.
1	Worm Gear Reducer	U 145 F, 15:1	Boston Gear Works, Atlanta, Ga.
1	Chain Sprocket	Diamond Cat H 100B30	Bearings and Drives, Atlanta, Ga.
1	Chain Sprocket	Diamond Cat H 1000A60	Bearings and Drives, Atlanta, Ga.
1	Chain	American Std #100SS	Bearings and Drives, Atlanta, Ga.
2	Ball Bearing	Fafnir 9110	Moffett Brgs. Co., Atlanta, Ga.
4	Ball Bearing	Fafnir 222W	Moffett Brgs. Co., Atlanta, Ga.
2	Ball Bearing	SKF 1222 Self Aligning	Moffett Brgs. Co., Atlanta, Ga.
2	Instrument	#17256, 50 Ckt	Electro-Tec Corp., Blacksburg, Va.
4	Flex Hose	8 FN Anchor	Mobesco, Atlanta, Ga.
1	Flex Hose	4 FN Anchor	Mobesco, Atlanta, Ga.
2	Flex Hose	12 FN Anchor	Mobesco, Atlanta, Ga.
8	Flex Hose Fittings	8 FN 6 MSR Anchor	Mobesco, Atlanta, Ga.
2	Flex Hose Fittings	4 FN 4 MSR Anchor	Mobesco, Atlanta, Ga.
2	Flex Hose Fittings	12 FN-12 MSR Anchor	Mobesco, Atlanta, Ga.
2	Flex Hose Fittings	12 FM-12 FJSR Anchor	Mobesco, Atlanta, Ga.
1	Magnetic Starter	Square D #8536 DW1-25 HP	Graybar Electric Co., Atlanta, Ga.

Quantity	Item	Nomenclature	Vendor
1	Transformer	440 VAC-110 VAC, 5 amps	Westinghouse Co., Atlanta, Ga.
1	Stop-Start Switch	Square D #9001 BW 40	Graybar Electric Co., Atlanta, Ga.
1	Quick Disconnect Body	121-006-07	Sunny Hill Research & Mfg. Co., Imperial, Pa.
8	Quick Disconnect Nipple	131-006-07	Sunny Hill Research & Mfg. Co., Imperial, Pa.
2	Quick Disconnect Body	121-004-07	Summy Hill Research & Mfg. Co., Imperial, Pa.
2	Quick Disconnect Nipple	131-004-07	Sunny Hill Research & Mfg. Co., Imperial, Pa.
2	Quick Disconnect Body	121-012-07	Sunny Hill Research & Mfg. Co., Imperial, Pa.
2	Quick Disconnect Nipple	131-012-07	Sunny Hill Research & Mfg. Co., Imperial, Pa.
1	Radiator	1962, 85 HP Ford Falcon	Beaudy Ford Co., Atlanta, Ga.

Note: All hydraulic tubing is type 304 stainless steel, which conforms to Mil Spec 8504-A. Stainless steel fittings are double ferrule type manufactured by Swagelock Co., whose local distributor is the Georgia Valve and Fitting Co., Atlanta, Georgia. Hydraulic fluid is Shell Tellus 15 or equivilent. All other items were manufactured by Georgia Tech and are detailed in Drawings No. A313-HR-101 through A313-HR-302.

VIII. LIST OF DRAWINGS

VIII. LIST OF DRAWINGS (Continued)